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VOLANT ADAPTATION IN VERTEBRATES

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OF THE several environments to which vertebrates have become adapted, the two which most profoundly modify their inhabitants are the water and the air. This is in part due to the fact that a homogeneous environment pressing upon all sides of the organism with almost the same intensity has moulded the form into a symmetrical contour which offers but little resistance in passing through the medium. In addition, special modifications of the limbs must occur, supplemented in air-inhabiting forms by cutaneous expansions or appendages for support or propulsion, without which very existence in the medium is out of the question.

Aquatic life modifies its denizens the more profoundly, because it becomes permanently sustaining, while even the best of fliers must ultimately return to the trees, the earth, or the sea. The aërial forms therefore always retain functional structures to enable them to move in the environment from whence their ancestors came. Of the more perfectly adapted aquatic types this is not true.

Creatures, other than the aquatic forms, can exist in the terrestrial realm without special adaptation; many forms which can climb fairly well may hardly be said to exhibit scansorial modification and indeed, while prolonged life in the water profoundly alters the contours of the animal, many vertebrates are fair swimmers whose proper environment is elsewhere. To venture into the aërial realm without an especial equipment for flight is to

court destruction like Darius Green, though many animals which cannot even soar, are wonderful leapers.

With the exception of the Amphibia, every class of vertebrates has developed true flight, while the power of soaring from a higher to a lower level has been acquired again and again.

Altogether no fewer than seventeen separate evolutions for aërial life have occurred among vertebrates, true flight five and probably seven[1] times, and soaring at least ten times. The forms which soar are singularly uniform in the plan of the sustaining mechanism and one would be justified in considering many of the volant mammals as the result of a single evolution were it not for the fact that in many cases the nearest relatives, which might prove annectant, are flightless forms. In true fliers, however, there is in each instance so distinct a plan of structure that there is not the slightest doubt that each has arisen through a separate evolution.

It is necessary to draw a sharp line of demarcation between the soarers and those having true flight, and the latter are again divided according to the mode of progression. These are, to use Marey's terms, the sailers, forms of great wing expanse like the vultures which rise slowly, but once in the air sustain themselves on almost motionless pinions; and the rowers or wing-flappers, such as have limited alar expanse and must make good this lack by a rapid vibration of the wings. This type culminates in the hummingbirds, though including many large birds of great speed as the wild goose. There are also gradational forms between the two extremes. Nor are these two methods confined to the birds, for among the pterodactyls it is evident that both kinds of true flight prevailed. Also, among the bats there are some of rapid wing movement, while others flap slowly, tending toward the sailing method of flight.

While the mode of flight is perfectly apparent in most aërial vertebrates, in some instances it has been difficult to assign the animal to the proper group as in the case of flying-fishes whose method of locomotion has given rise to much argument. Moseley's description of the flight of the albatross (Moseley, '79, p. 570)

[1] I am not sure under which head the fossil flying-fishes should come; but unless their fin-wings were far larger proportionately than those of modern types Colonel Durnford's argument would hold good for them as well and would place them among the true fliers (*vide infra* p. 541).

is another instance of the correction of a popular misconception due to a lack of knowledge of mechanical principles, for while vultures, when sailing, are continually sliding down an inclined plane, the albatross was supposed to sail close to the sea without losing altitude; a manifest impossibility.[1]

Classification

Volant vertebrates may be classed as follows: —

Evolution			Soaring	Flapping	Sailing
	Pisces				
1	Ganoidei	Thoracopterus		×	
2		Gigantopterus		×	
3	Teleostomi	Exocœtus		×	
4		Dactylopterus		×	
	Amphibia				
5	Anura	Rhacophorus	×		
	Reptilia				
6	Squamata	Ptychozoön	×		
7		Draco	×		
8	Pterosauria	(entire order)		×	×
9	Aves	(entire class)		×	×
	Mammalia				
10	Marsupialia	Ptauroides	×		
11		Petaurus	×		
12		Acrobates	×		
13	Rodentia	Anomalurus	×		
14		Pteromys, Sciuropterus, Eupetaurus	×		
15	Insectivora	Galeopithecus	×		
16	Chiroptera	(entire order)		×	
17	Primates	Propithecus	×		
	Total		10	7	2

In all 17 evolutions.

[1] Moseley says: "I believe that Albatrosses move their wings much oftener than is suspected. They often have the appearance of soaring for long periods after a ship without flapping their wings at all, but if they be very closely watched, very short but extremely quick motions of the wings may be detected. The appearance is rather as if the body of the bird dropped a very short distance and rose again. The movements cannot be seen at all unless the bird is exactly on a level with the eye. A very quick stroke, carried even through a very short arc, can of course supply a large store of fresh momentum. In perfectly calm weather, Albatrosses flap heavily."

FISHES

The flying adaptation among fishes has occurred at least four times; twice among recent fishes and fully as often during geological times. Dr. O. Abel in the last *Year-book of the Austrian Geological Survey*, describes and figures two ganoid flying-fishes from the New Red Sandstone (Upper Trias). These are Thoracopterus and Gigantopterus and they differ totally from the modern types except in the development of wing-fins for flight. They

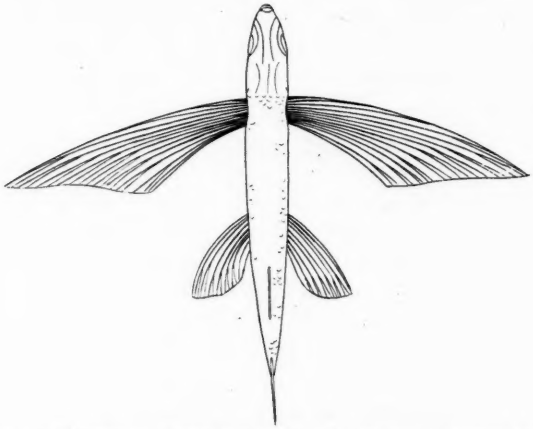

FIG. 1.— *Exocœtus* sp., drawn from an alcoholic specimen. ½ natural size.

resemble their non-flying contemporaries in the possession of quadrangular, enamel-covered scales which encased the body.

Of modern types two important genera of Teleostomi have acquired flight, Exocœtus, a herring, and Dactylopterus, a gurnard.

Exocœtus.— This genus embraces forty-four species which are generally known as the true flying-fishes in contradistinction to the flying-gurnards or gurnets mentioned above.

In Exocœtus flight modification consists in the elongation and broadening of the pectoral fins and a lesser enlargement of the pelvics as well; so that the weight while in the air is distributed, though unequally, between the two sets of fins as shown in Fig. 1. The anterior fin-rays are much strengthened, especially toward

their base, while distally each ray bifurcates to give more support to the flying membrane. The lengthening of the pectoral fins varies with the species, being greatest in those with the best powers of flight.

The bodily contour seems to have suffered but little alteration due to the development of flight. The lower lobe of the caudal fin is much the longer and thus becomes more efficient in giving the fish its final impetus upon leaving the water. It is also said that the fin is occasionally submerged during flight and aids in changing the direction of the fish.

Nearly all of the Scombresocidæ, to which family this flying-fish belongs, have the power of taking great leaps out of the water, culminating in Exocœtus. In the development of the pectoral fin every gradation may be found between the small pectorals of Scombresox to Exocœtus, Hemiexocœtus being a very remarkable connecting form (Boulenger).

Exocœtus is tropical to subtropical in distribution, some species having an extremely wide range.

The manner of the flight of flying-fishes has been a much vexed question, one idea being that the creature gets its impetus solely from the tail while in the water, the wings acting merely as parachutes or aëroplanes to support the animal in the air. The other view is that while the initial start is given by the tail, flight is sustained by an actual vibration of the fins as in wing-flapping birds and bats. Some authorities have maintained that the fins move voluntarily only at the beginning and end of the flight, others that this apparent movement is due to an occasional vibration caused by the currents of air.

Colonel Durnford in the January number of the *American Naturalist*, has effectually settled the question by showing that sustained soaring for such a distance (500 feet, Günther) is a mechanical impossibility, due to the moderate initial speed, for a creature of such limited wing-area in proportion to its weight. He further shows that not only is wing vibration necessary, but vibration at extreme speed, such as is invisible to most eyes except at the beginning and end of the flight when the fins are accelerating or retarding their velocity. This is in spite of the statement of Möbius ('78, p. 343) who after examining the musculature as well as watching

the living fish came to the conclusion that the fins are not moved at all.

Dactylopterus.— In Dactylopterus the pectoral fins are especially developed for flight and they alone give support to the body in the air as the pelvic fins, which are situated just beneath the pectorals, are not visible from above even when extended. The pectoral fins as a compensation are much broader than in Exocœtus, the relative alar expanse compared with the bulk of the body being much the same in the two genera (compare Figs. 1 and 2).

In the present form the entire body is heavier and of more robust

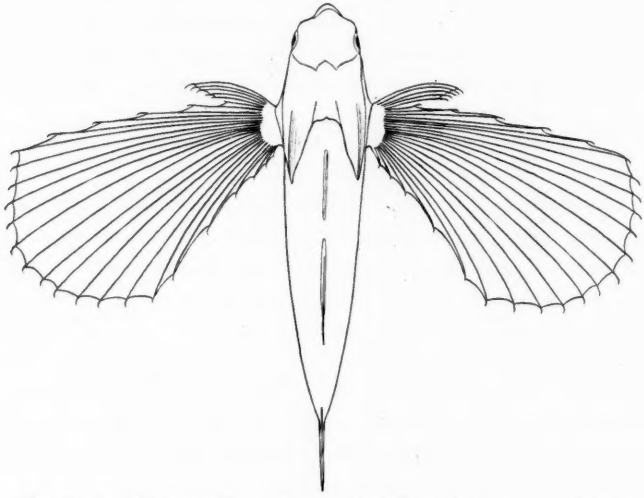

FIG. 2.— *Dactylopterus volitans.* From an alcoholic specimen. ¼ natural size.

build and the strongly armored head is flattened beneath. The tail in Dactylopterus is symmetrical, not with a larger lower lobe as in Exocœtus.

The pectoral fins, aside from their greater breadth, differ from those of the latter genus in having more membrane in proportion to the supporting fin-rays, making a less rigid organ. In the young flying-gurnards, formerly thought to represent a distinct genus, Cephalacanthus, the pectorals are so much shorter than those of

the adult that they are unable to raise themselves out of the water (Günther).

Moseley ('79, p. 571) says: "I have distinctly seen species of Flying Gurnets move their wings rapidly during their flight .... especially in the case of a small species of Dactylopterus with beautifully coloured wings, which inhabits the Sargasso Sea." He further says that he has never seen any species of Exocœtus flap its wings which must be taken as indicating that in Dactylopterus the movement is much slower so as to be distinctly visible. This one would be led to expect from the feebler wing structure and the result is a much less developed power of flight. Moseley likens the flight of the gurnets to that of grasshoppers.

Boulenger (:04, p. 701) recognizes four species of Dactylopterus which are found in "the tropical and warm parts of the Atlantic and Indian Ocean and Archipelago."

Amphibia

The only volant adaptation among the Amphibia is that of the tree frog, Rhacophorus, in which the webbed feet bear the creature

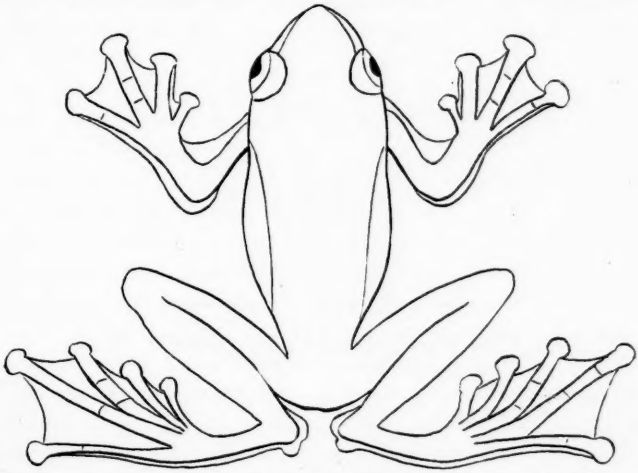

Fig. 3.— *Rhacophorus rheinhardtii.* After Duméril and Bibron. Natural size.

up during the prolonged leaps that it takes from tree to tree.

This genus includes more than forty species and has a wide dis-

tribution in the paleotropical realm. It was first described by Wallace ('69, p. 38) who evidently through error exaggerated the extent of the supporting membranes very much. The generic name is derived from the presence of the small dermal flaps seen especially at the heel.

The digits terminate in adhesive pads and are connected by web-like expansions of skin which also extends between the two outer metatarsals. Membranes are developed as well in front and behind the arms, rudiments of the prepatagium seen in higher forms.

The figure (Fig. 3), which is modified from that of Duméril and Bibron ('36, pl. 89), is that of *Rhacophorus rheinhardtii* and shows a very conservative development of the parachute, though in the majority of species the web extends not more than half the length of the fingers. In *Rhacophorus pardalis* the total alar expanse is about three square inches (Gadow). This would imply rather feeble soaring powers.

REPTILIA

Reptilia exhibit at least three instances of volant adaptation, the most notable instance being that of the extinct Pterosauria in which

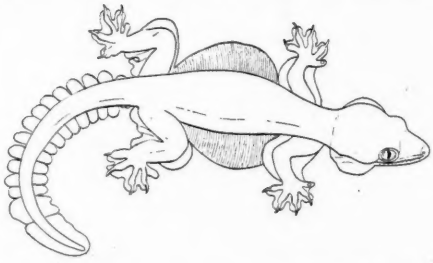

FIG. 4.— *Ptychozoon homalocephalum*. After Duméril and Bibron.

true flight was developed, the special adaptation of the entire organism being second only to that of birds.

Lacertilia.— Among modern types two lizards have the power of soaring, though in varying degree.

Of these lizards the first is of the family Geckonidæ, *Ptycho-*

zoön homalocephalum, a remarkable form from the Malay Islands and the Malay Peninsula. This creature, shown in Fig. 4, is about eight inches in length, a typical gecko in foot structure, but with membranous expansions along the sides of the head, limbs, body, and tail. The membrane also extends between the digits as in Rhacophorus. The membrane of the tail consists of a series of short flaps on either side. These extensions of the skin seem to be unsupported in contrast to those of Draco, but subserve the same function of supporting the creature in its soaring leaps.

The membranes are discernible in the newly hatched young (Gadow).

In *Draco volans* of the family Agamidæ, the supporting membrane is limited to the sides of the trunk and is of ample extent, well supported by the ribs of which five or six pairs extend beyond the body wall as shown in Fig. 5. The membrane is capable of being closed like a fan against the sides of the body, and its efficiency as a buoyant organ is increased by the concavity of the inferior surface.

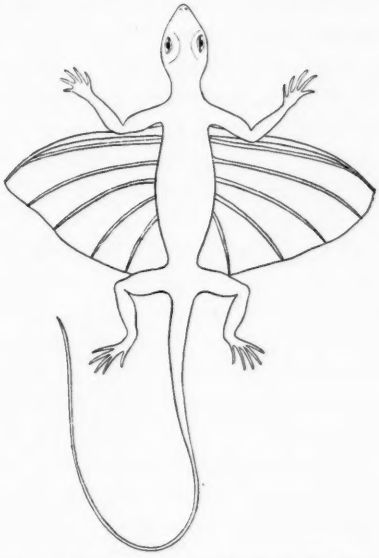

FIG. 5.— *Draco volans*. From a mounted specimen. ½ natural size.

The body is strongly depressed and the tail is extremely long and slender and must aid the creature in guiding its flight.

There are in all about twenty species of Draco, inhabiting the East Indies. The power of flight is not very great, but probably exceeds that of Ptychozoön.

PTEROSAURIA

The pterodactyls were a remarkable group of reptilian forms whose remains are known from the Mesozoic rocks, ranging from the Rhætic to the Upper Chalk. As yet we know nothing of their ancestry, for the first which appear are in every way characteristic of the group.

Seeley (:01, p. 229) says: "There is no geological history of the rapid or gradual development of the wing finger, and although the wing membrane may be accepted as the cause of its existence the wing finger is powerfully developed in the oldest known pterodactyls as in their later representatives.

"Pterodactyls show singularly little variation in structure in their geological history. We chronicle the loss of the tail and the loss of teeth. There is also the loss of the outermost wing-digit from the hind foot as a supporter of the wing membrane. But the other variations are in the length of the metacarpus, or of the neck, or of the head." One might add to this an increase of size as the huge pterodactyl Pteranodon and its allies are among the last to appear.

The adaptation of the pterodactyls for flight is a very perfect one, implying not only the development of true wings, but a specially modified respiratory apparatus coupled with a highly developed pneumaticity of the bones as in birds. There is also a very bird-like modification of the brain which is unlike that of any other reptile. This is seen especially in the width of the hemispheres which touch the well developed cerebellum. On each side of the cerebellum lie the optic lobes while the flocculi, lateral appendages of the cerebellum, which are known elsewhere only in birds, are well developed (Gadow).

Skull.— The skull resembles that of birds, exhibiting large vacuities in some forms and bearing well developed teeth set in distinct sockets and varying in size. In Pteranodon and its allies the jaws were toothless and were evidently not sheathed with horn but with a leathery skin, indicating probably fish-eating habits. Posteriorly, the skull of Pteranodon is prolonged into a compressed,

vane-like process evidently not for muscular attachment but to aid in keeping the head pointing into the wind. This would otherwise not only require great muscular effort but would probably have deflected the creature from its course. The head is articulated at right angles with the neck as in birds and in bipedal dinosaurs.

Wings.— The wings consist of the patagium, a broad expanse of membrane, supported by the fore and hind limbs, a prepatagium in front of the arm, and an interfemoral membrane extending between the hind limbs and the tail. The patagium was delicate and very similar to that of the bats. The surface was marked with delicate striæ, which seem to be minute wrinklings. The membrane, when not extended, was thrown into longitudinal folds.

Fore Limb and Girdle.— The skeleton of the fore limb and girdle

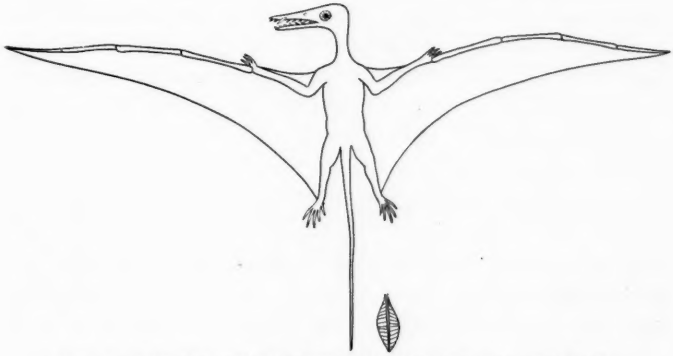

FIG. 6.— *Rhamphorhynchus phyllurus.* Modified from Marsh and Zittel. About ⅛ natural size.

shows a remarkable modification for the purposes of flight, differing markedly from either the bird or the bat. The pectoral arch is reduced to two pairs of elements, the scapulæ and coracoids, as the clavicles are entirely wanting. In the forms existing before the Cretaceous period the scapulæ are saber-shaped and are united with the coracoids at an angle of less than 90° exactly as in carinate birds. The Cretaceous pterodactyls differ, however, in that the scapulæ, while articulating at right angles with the coracoids, are directed toward the vertebræ uniting with their neural arches. In Pteranodon the scapula articulates with the coalesced spines

of several coössified vertebræ, being, as Marsh says, "virtually a repetition of the pelvic arch, on a much larger scale" (Marsh, '82, p. 254).

The sternum is large with a carina or keel, especially in the anterior part, which extends forward in front of the coracoid articulations. The keel is but feebly developed in the great sailing forms like Pteranodon while on the other hand it is very high in Rhamphorhynchus which evidently flew by flapping the wings rapidly. The coracoids unite with the sternum by a true synovial joint.

The most notable feature of the humerus is the form of the proximal articular surface which is saddle-shaped, being concave along the horizontal axis and convex vertically. There is also a remarkable development of the radial crest.

The ulna and radius are nearly of the same size, the latter being

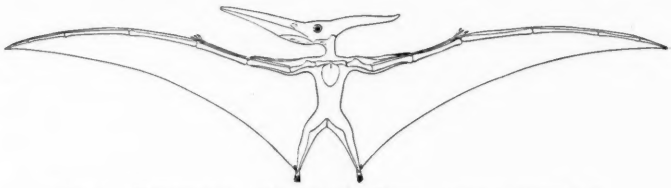

FIG. 7.— *Pteranodon* sp. Modified from Eaton. About $\frac{1}{54}$ natural size.

somewhat smaller, while of the metacarpals, that of the wing finger is of great size and strength while those of the three preceding digits are very slender bones. The joint for folding the wing is between the metacarpals and phalanges, not at the wrist as in birds.

The number of digits is probably five as there are two bones articulating with the distal carpal on the inner side of the wrist which Marsh ('82, p. 254) interprets as the metacarpal and first phalanx of the first digit. The phalanx, which he calls the "pteroid bone," formed part of the support for the prepatagium, being directed inward toward the shoulder. Others have interpreted this bone as an ossified tendon. If Marsh is correct the number of digits would be five, the fifth being the wing finger.

Hind Limb and Pelvis.— The pelvis is crocodilian in character, while the hind limbs are bird-like with splint-like fibulæ and long, slender tibiæ. The feet have long metatarsals bearing five digits.

In Dimorphodon and other long-tailed forms the outer digit resembles somewhat that of the hand, only on a much smaller scale. It probably also aided in the support of the patagium. In the short-tailed types, on the contrary, this digit is reduced to a vestige without phalanges.

I have figured for comparison two notable genera, the types of which may each be found in the Yale University Museum. Of these, Rhamphorhynchus, representing the suborder Pterodermata Seeley, is a small form from the Solenhofen Slate with a long tail terminating in a peculiar vertical rudder-like expansion supported by neural spines above and by the chevron bones below. This was undoubtedly for steering (Fig. 6).

The other form, Pteranodon (Fig. 7), belongs to the suborder Ornithocheiroidea of Seeley. It is from the Kansas Chalk, a creature with an alar expanse of eighteen feet! Vast in comparison with the diminutive body. In Pteranodon the tail is reduced to a vestige which afforded but little support to the interfemoral membrane. If one may judge from the relation of wing expanse to the size of the body it would seem as though Pteranodon must have had a sailing flight, flapping the wings slowly if at all. It may have been similar to the albatross (*vide supra*, p. 539) in habits of flight, or it may have been unable to fly except on a windy day when, by facing the wind, it would be able to rise to a considerable altitude before its inertia was overcome. Rhamphorhynchus on the other hand was probably a more active flier exhibiting the wing-flapping method of flight.

Birds

The birds form a remarkably homogeneous group reaching the climax of volant adaptation. Flight has, however, been lost in some of the more specialized forms as the penguins among the Carinate birds and in the whole group of so called Ratite birds.

In brief, the modifications for flight consist in the alteration of the fore limb into a wing with a reduced hand and with slightly developed pre- and postpatagiums, but with the alar expanse increased by the development of the feathers. The tail also becomes an

efficient steering organ and adds materially to the support of the animal in the air as well. Aside from the bodily conformation which is such as to offer but little resistance to the air in passage, the respiratory organs seem to show the best adaptation to its mode of life of all the other mechanisms of the bird.

A very interesting series of comparisons may be made between the birds and the pterodactyls which must be explained as the result of convergence, though the evidence of a common ancestry for the two groups is very strong. Other characters there are in common with the dinosaurs, explicable in the same way, but these can hardly be said to be volant adaptations as we have no evidence that the dinosaurs acquired flight.

Fore Limb and Girdle.—The fore limb and shoulder girdle are wonderfully adapted to their purpose. In the pectoral arch all three elements are represented in contrast to the coracoid and scapula in the pterodactyls and the clavicle and scapula in the bats. The clavicles have united ventrally to form what is technically known as the furculum which does not always articulate with the sternum. The scapulæ and coracoids fuse with each other firmly, forming in the Carinatæ an angle of less than 90° as in the earlier pterodactyls, while in the Ratitæ the angle formed is greater than 90°, a feature associated with the loss of flight.

The scapula is saber-shaped, and lies parallel with the vertebræ, with which it never articulates as in the later pterosaurs. The coracoid is a massive, pillar-like bone firmly articulated with the sternum. Its duty is to withstand the stress of the great pectoral muscles which would pull the shoulder toward the breast-bone were it not for the resistance offered by the coracoid.

The sternum is large, covering in the Carinatæ much of the ventral wall of the chest and it bears along its midventral line a high keel or carina for the origin of the muscles of flight. In the Ratitæ the keel is wanting, having been lost with the reduction of the pectoral muscles. In pterodactyls the sternum is similarly keeled, though to a less extent, in the smaller forms which had flapping flight. The keel becomes obsolete except upon the forwardly projecting process of the sternum in such huge forms as Pteranodon which, as we have seen, were probably sailers.

In the carinate birds the humerus is notable mainly for the size of the crests which afford attachment for the various muscles. The humerus is reduced in those birds which have lost the power of flight and may be entirely absent as in many of the moas.

Seeley (:01, p. 47) tells us of the remarkable similarity which exists between the foramen in the humerus of the pterodactyl and that of the bird, by which air enters the cavity of the bone. He says: "In the Pterodactyle the corresponding foramen has the same position, form, and size, and is not one large hole, but a reticulation of small perforations, one beyond another, exactly such

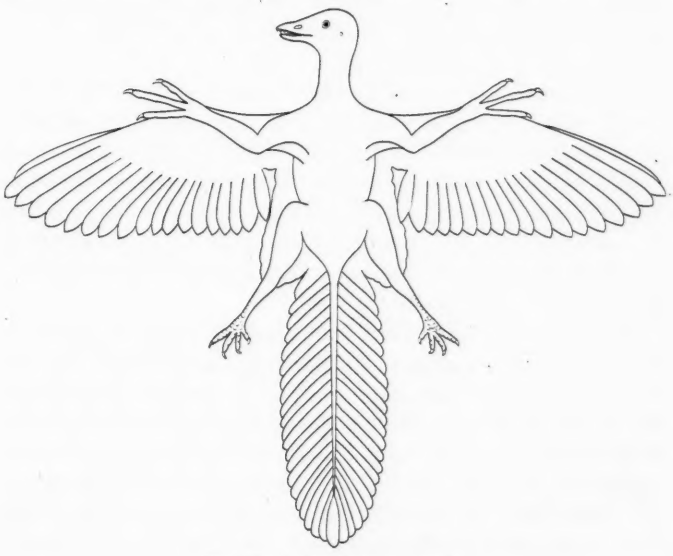

FIG. 8.— *Archæopteryx macroura.*

as are seen in the bone of a bird in which the pneumatic character is found."

There are in modern birds but three unequally developed metacarpals which are firmly coössified. The digits are represented by one, or rarely two, phalanges in the pollex which supports the bastard wing, while the second digit, which is much the largest, bears two, and the third one phalanx. Claws are sometimes borne on

the first and second digit in modern birds; in Archæopteryx upon the third as well.

Archæopteryx exhibits naturally a more primitive condition of structure than do modern birds, but even here the features are truly bird-like. The sternum is not well known, but the furcula and the coracoids are like those of existing birds. The wing is shorter in Archæopteryx with rather slender bones; the humerus is somewhat longer than the radius and ulna. But one carpal bone is known though at least one other must have existed. The three metacarpals are free and each bore a well developed digit terminating in a claw. We do not know whether the second bore any of the contour feathers as in modern birds or whether they were all borne on the third finger.

Hind Limb and Pelvis.— The hind limb and pelvis of birds can hardly be said to exhibit volant adaptation, unless it be in the development of pneumaticity, as their structure is so closely paralleled in certain of the dinosaurs. It seems rather that the dinosaur-avian type of limb, or the tendency to acquire it, is an inheritance from a common ancestor which certainly could not have possessed the power of flight as the dinosaurs show no evidence of having had and lost this characteristic.

Tail.— The tail of the bird shows a distinct flight modification less developed, however, in Archæopteryx in which the tail was elongated and lizard-like and bore a pair of oppositely placed feathers on each segment. These evidently were used for steering and must have afforded a good deal of support to the body as well, in compensation for the comparatively small wings. The Neornithes or modern birds, on the other hand, have shortened tails, several of the terminal vertebræ having fused to form a pygostyle. Around this vestigial tail the rectrices are arranged fan-wise making a very efficient organ for steering and for checking the rapidity of flight.

A comparison of the figure of the pigeon (Fig. 9) with that of Archæopteryx (Fig. 8) is interesting as showing the increase in the expanse of the wings to compensate for the reduction of the tail so that the relative buoyant surface remains approximately the same.

The Trunk.— The rib structure of the Neornithes must be considered as a definite flight modification for here only do we find the

sternal and vertebral ribs articulating by a true synovial joint. This, together with the elbow-like flexion of the joint, forms an admirable mechanism for the dorso-ventral increase and decrease of the chest cavity during respiration. When the bird is resting the back is rigid and the sternum moves, but during flight when the sternum is supporting the creature it is the back which rises and falls.

The long slender neck and the tendency on the part of the trunk vertebræ to coössify, are further skeletal characteristics of birds.

Respiratory Organs.— While all of the nutritive organs are necessarily larger and more efficient in birds as the direct result of more

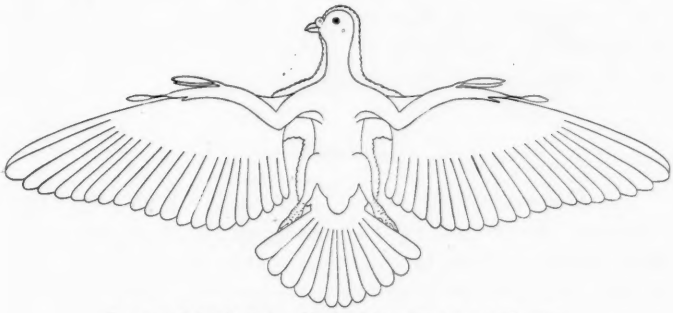

FIG. 9.— *Columba livia.* Modified from Parker and Haswell.

rapid expenditure of energy during flight, the respiratory organs show the most remarkable adaptation. The lungs are inelastic and do not hang freely in the cavity of the chest as do those of mammals, but are connected with an extensive series of air sacs, principally in the abdomen, but in other portions of the body as well. These serve not only to lighten the specific gravity of the bird, but, by means of the abdominal sacs, air is drawn *through* instead of merely into the lungs with the result that the air in the latter is entirely renewed with each inspiration. There being thus no residual air, the entire lung functions for the aëration of the blood. The respiratory system is further connected with the cavities within the bones as in pterodactyls and while this pneumaticity is evidently an aid to flight as it reaches its maximum development in such powerful fliers as the pelicans, it is on the other hand but little

developed in the gulls which are also strong of wing. Seeley says: "Comparison shows that in so far as the bones are the same in the bird and ornithosaur, the evidence of air cells entering them extends to resemblance, if not coincidence in every detail. No living group of animals except birds has pneumatic limb-bones, in relation to the lungs; so that the identical structures in the bones were due to the same cause in both living and extinct groups of animals" (Seeley, :01, p. 50).

Brain.— In the avian brain the convergence[1] toward that of the pterodactyl lies in the position of the optic lobes which are laterally displaced so that the cerebrum may extend between as well as over them in order to abut against the cerebellum. There is also a similarity in the development of the lateral lobes or flocculi upon the sides of the hind brain. These features seem to be adaptations correlated with the development of flight.

MAMMALIA

The Mammalia show at least eight distinct flight evolutions. In seven instances soaring has been developed as an aid to prolonged leaps, while the Chiroptera as an order are true fliers. This should not surprise us for all but one of the forms are arboreal and with arboreal types the development of parachutes for sustaining the creature in the air during its passage from tree to tree is a logical course of evolution.

Marsupialia

Among the marsupials of the family Phalangeridæ there are three genera, Petauroides, Petaurus, and Acrobates, which have independently acquired the power of soaring; for the three genera are each in turn especially related to a separate type of non-flying phalanger. The same observation can be made about the flying squirrels, Anomalurus and Sciuropterus (Beddard).

[1] Dr. F. B. Loomis is of the opinion that the brain similarity is due to real relationship and is not a convergence. He explains in the same way the similarity of the openings into the pneumatic bones.

In all of these forms the flight adaptation consists mainly in the development of a horizontal fold of skin (the patagium) stretched along the sides of the body between the fore and hind limbs.

Petauroides.— In Petauroides the flying membrane extends from the wrist to the ankle, but is very narrow along the lower segment of each limb. The tail is very bushy except for its prehensile tip which is naked inferiorly, and, together with the long fur which clothes the body, must aid considerably in buoying the creature up while soaring.

Petauroides includes but a single species, *P. volans*, the so called Taguan flying phalanger, found in Australia from Queensland to Victoria. Its nearest ally is Dactylopsila which, however, has no flying membrane but has the same partially naked tip to the tail.

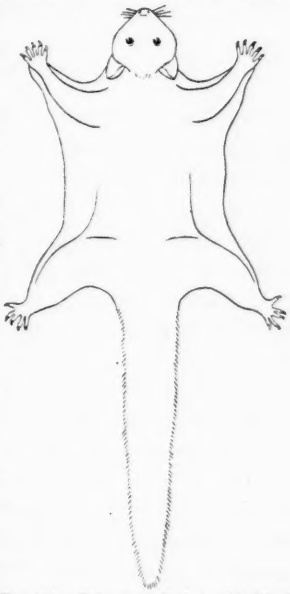

FIG. 10.— *Petaurus sciurius.* Modified from Flower and Lydekker.

Petaurus.— Petaurus has a much broader patagium which extends from the outer finger to the tarsus; there is also a slight extension of membrane in front of the fore limb. The tail is very large and evenly bushy, lacking the naked tip. This genus contains three species which are somewhat smaller forms than Petauroides. They seem to have been derived either from the genus Gymnobelideus, which resembles Petaurus closely except that it is flightless, or from an allied extinct form (Lydekker).

The geographical range of Petaurus is "over New Guinea and part of Australia, including the area from the Halmahéra group of Islands to Victoria."

Acrobates.— The third genus, Acrobates, contains two species of which the individuals are of small size with a narrow patagium extending from the elbow to the knee along the flank. The buoy-

ant area is increased, however, by the long fringing hairs. There are striated pads at the extremities of the digits. The probably prehensile tail has its long hairs arranged on either side as in its near ally, the pen-tailed phalanger, Distæchurus, which from its skull and teeth may be very close to the ancestral type of Acrobates.

One species, *Acrobates pygmæus*, is found in Queensland, New South Wales, and Victoria and the other, *A. pulchellus*, in Papua, while Distæchurus is now found in New Guinea. Acrobates is extremely active with great soaring powers.

Rodentia

Two families of rodents, the Anomaluridæ containing but one flying genus Anomalurus, and the Sciuridæ containing among others the flying genera Pteromys, Sciuropterus, and Eupetaurus, have developed the power of soaring by means of a patagium.

These families represent in each case a distinct adaptation to volant life, though the three genera of the Sciuridæ are closely related and are not as in the Phalangeridæ, related each in turn to a non-flying ally. The convergence of the flying rodents toward the flying phalangers is very marked though the former are apt to develop more or less of a prepatagium and an interfemoral membrane in addition to the patagium along the flanks. This is, however, as will be shown, a variable feature.

Anomalurus.— The Anomaluridæ include three genera of which Anomalurus with six species is the most important. In this genus the patagium is well developed and is supported by a cartilaginous process of the olecranon. The membrane extends from the carpus to the tarsus but narrows along the front of the leg from the knee down. This is compensated for by an interfemoral membrane from the heel to the tail a little beyond its base.

A distinctive feature of these forms, while not a volant adaptation but rather an arboreal one, is the presence of imbricated, keeled scales beneath the tail which apparently aid in climbing. The tail is not very bushy so that it probably aids but little in flight.

Anomalurus resembles Pteromys but is distinguished therefrom

and from Sciuropterus by the caudal scales and by the position of the supporting cartilage. Anomalurus is African in habitat.

The allied genus, Idiurus, differs in minor details from Anomalurus, while Aëthiurus from the French Congo, has no flying patagium.

Pteromys.— Among the Sciuridæ, Pteromys has a patagium extending as far as the digits and supported as in Anomalurus, by a cartilage, but one arising from the carpus rather than from the

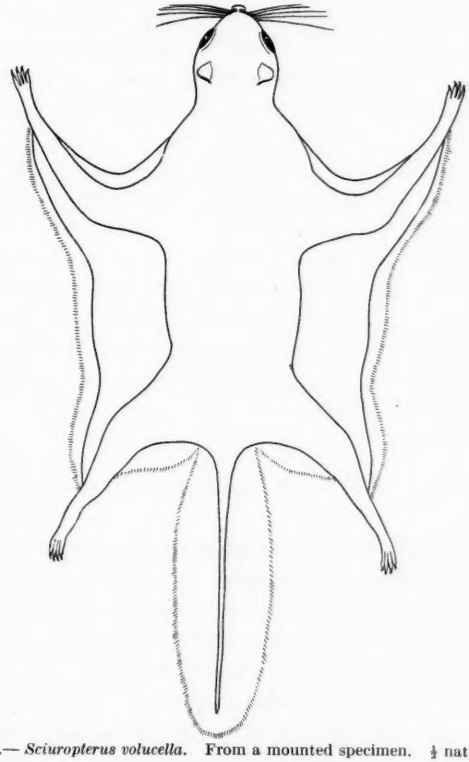

FIG. 11.— *Sciuropterus volucella.* From a mounted specimen. ½ natural size.

olecranon. In addition to the interfemoral membrane extending to the root of the tail, there is also a narrow prepatagium running from the anterior limb to the sides of the cheeks. The tail

is larger than in Anomalurus and must add materially to the support of the body in the air. It is said that Pteromys can soar through a distance of nearly eighty yards, depending of course upon the initial altitude above the ground.

Pteromys is found in the "wooded districts of tropical southeastern Asia, Japan, and some of the Malaysian Islands" (Heilprin).

Sciuropterus.— Sciuropterus, which is here figured (Fig. 11), has no interfemoral membrane, but as a compensation, the tail is much more fully developed than in Pteromys. In the latter it is round and comparatively thin while in Sciuropterus the tail is flat and broadly expanded. A hairy fringe extends beyond the margin of the patagium and behind the femora as well, thus extending the supporting area as the figure clearly shows.

Sciuropterus includes smaller forms than Pteromys, but its range is much more extensive as it includes the northern part of North America and the Eurasian continent.

Eupetaurus.— Eupetaurus resembles Pteromys but has no interfemoral membrane. It differs from the preceding forms mainly in having hypsodont teeth rather than brachyodont which implies a difference in feeding habits. Eupetaurus is rock- and precipice-inhabiting rather than arboreal and inhabits the high elevations of northwestern Kashmir.

Insectivora

Among the Insectivora, Galeopithecus stands alone in its volant adaptation for it shows the greatest specialization for flight of any of the Mammalia except the bats. Indeed Galeopithecus, while too specialized to be ancestral to the Chiroptera, is evidently from a common stock and gives us a pretty clear idea of the characters of the forms from which the latter arose.

In Galeopithecus, which is an animal of considerable size, the patagium is well developed and is supplemented by a prepatagium and an interfemoral membrane which includes the entire tail precisely as in the insectivorous bats. The patagium is well supplied with muscles and nerves which are homologous with those in the

wing membrane of the Chiroptera and differ decidedly from those of the other volant Mammalia.

The hand is much larger than the foot and the flying membrane is continued along the side of each as well as between the digits, and while the fingers show no trace of the elongation so characteristic of the bats, if such were to occur the result would be a very bat-like structure.

Galeopithecus is unique in the character of the teeth which are adapted to a phytophagous or leaf-eating habit, while the alimentary canal resembles that of the Chiroptera except that in Galeopithecus the colon is long, while in bats as in birds the colon is very short. This shortening of the colon is clearly a volant character due to the freedom with which excrement may be voided by

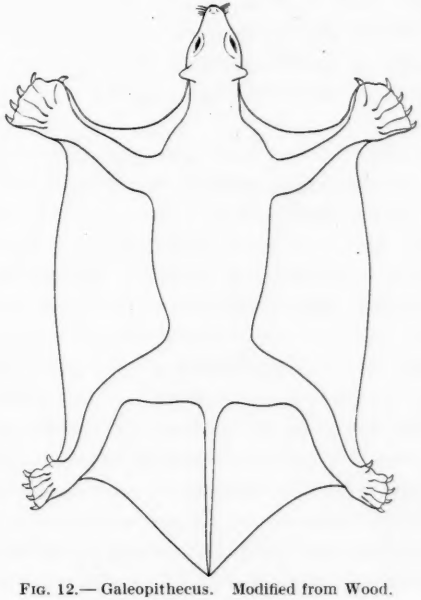

FIG. 12.— Galeopithecus. Modified from Wood.

aërial forms and the consequent lack of necessity for a place of storage of effete matter.

The brain in Galeopithecus is midway in its development between that of a typical insectivore and that of a bat.

Galeopithecus is nocturnal in habits, as indeed almost all volant mammals are, resting during the day by clinging head downward from the branch of a tree, in which posture it resembles Pteropus very closely. Its soaring powers are very great as one has been seen to cover a space of seventy yards with a descent of not more than thirty-five or forty feet, or less than one in five (Wallace).

Two species of Galeopithecus are known, one, *G. volans*, from the Malay Peninsula, Sumatra, and Borneo, while *G. philippinensis* inhabits the Philippine Islands.

Chiroptera

In the bats one sees the culmination of volant adaptation on the part of the Mammalia and the entire order has reached a state of perfection excelled only by the birds and pterodactyls. Each of the three solely air-breathing classes of vertebrates has, in one line of evolution at least, culminated in perfect adaptation to aërial life.

The bats while showing the same general plan of structure throughout, are divisible into two distinct suborders in which constant distinguishing characters have arisen, due to differences of habits. These are the Microchiroptera and the Megachiroptera the former being in the main insectivorous while the latter are frugivorous in habits. Each group, however, contains some aberrant forms.

The Patagium.— The most notable volant characters are the great development of the digits of the hand supporting the patagium which extends along the sides of the body and hind limb to the tarsus. There is a well developed prepatagium extending from the neck to the wrist. An interfemoral membrane is also present, but varies in development in the two suborders, including the somewhat elongated tail in the Microchiroptera, while in the tailless Megachiroptera each membrane is a triangular area meeting its fellow at the end of the spine. In the Microchiroptera the membrane is further supported by a cartilaginous rod, the calcar, arising from the heel and directed obliquely inward toward the tip of the tail. The development of the tail gives, with the interfemoral

membrane, an efficient organ for steering and checking the way of the animal during flight, so necessary in the pursuit of insects and which gives to the twilight bat its characteristic flight. It is also said that this structure is of use in the capturing of prey.

In the vampire and other aberrant carnivorous Microchiroptera, there is no tail, a point of agreement with the frugivorous forms. The tailless bats are much heavier fliers as a rule, flapping their way slowly through the air.

The patagium is naked, being clothed with hair along the sides

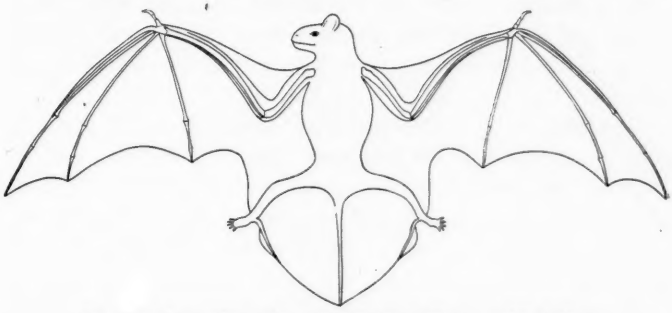

FIG. 13.— *Vespertilio noctula*. Modified from Flower and Lydekker.

of the body only, and the surface of the integument is finely wrinkled as in the pterodactyl Rhamphorhynchus. The method of folding the wing when at rest is also the same. The contrast between the wing of the bat and that of the pterodactyl is in the support of the membrane in the former by four digits, only the pollex being free, while in the latter the outermost finger alone supports the wing membrane. The contrast with the bird lies in the reduction of the digits in the latter to three and in the retrogression of the patagium whose place as a buoyant surface is taken by the feathers.

The Fore Limb.— The pollex is always free and clawed and aids in crawling on level ground, but more especially in climbing. In the Microchiroptera the second finger while distinct is not free but is attached to the third distally so that the two together support the anterior margin of the wing. The third finger, however, is much the longest and digits four and five are well developed and free.

In the Megachiroptera the contrast lies mainly in the difference in wing proportions due to the fact that the second digit is free from the third and supports a portion of the patagium alone. It is further clawed at the tip. A comparison of Figs. 13 and 14 will render these distinctions clear.

The bones of the wing are very slender with large medullary cavities, but without any trace of pneumaticity as in birds and pterodactyls. The shoulder girdle, consisting of well developed clavicles and scapulæ, is very strong. The clavicles are curved and the scapulæ bear strongly curved coracoid processes. The humerus is well developed but is much exceeded in length by the radius which is a strong, curved bone while the ulna is much reduced.

The Hind Limb.— One chiropteran peculiarity which is clearly a flight adaptation is the backward rotation of the hind limb so that the knee points towards the rear instead of toward the front as in quadrupeds. This feature is a distinct disadvantage for terrestrial locomotion, making the creature extremely awkward when upon the ground.

There are five compressed digits in the pes bearing long, curved claws and used as in Galeopithecus for suspending the creature head downward when at rest.

The Trunk.— The chest is remarkably capacious to contain the large lungs and heart which resemble those of birds in their state of development.

The vertebral column is short owing to the compact form of the body and the individual vertebræ have but little movement and tend to coössify in old age. The neural canal is largest in the cervical and thoracic regions, rapidly diminishing toward the rear. This is due to the large size of that portion of the spinal cord from which the great muscles of flight are innervated as contrasted with the feeble development of the posterior portion of the body.

The presternum has a well developed keel as in birds and pterodactyls for the origin of the muscles of flight.

The Brain and Sense Organs.— While the brain of the Chiroptera is of as lowly organization as the most nearly allied order, the Insectivora, certain senses of the bats, especially that of touch,

have undergone a remarkable degree of development and refinement. This tactile sense seems to reside mainly in the vibrissæ, in the wing membrane, and in the ear pinnæ which in some types are very large. More especially is the sense developed in the leaf-like expansions of the skin about the nose and face in the Rhinolophidæ and Phyllostomatidæ. These appendages are the seat of so delicate a sense of touch that actual bodily contact with an object

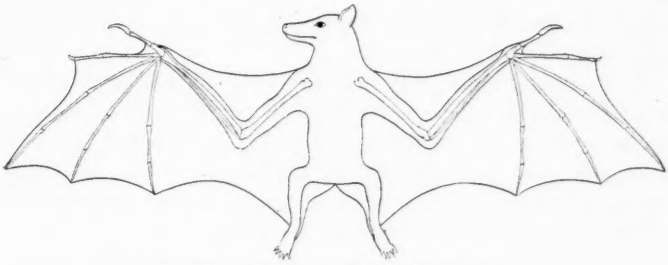

FIG. 14.— *Pteropus* sp. Modified from Owen.

is not necessary to its perception, but the reflected aërial waves suffice to stimulate the sense organ. This is a notable secondary flight adaptation, not useful as a direct aid to flight, but in guiding a rapidly moving nocturnal flier it must prove invaluable.

The Chiroptera are practically world-wide in distribution, being found wherever sufficient food may be procured.

Primates

Among the primates one genus exhibits a small patagium which aids in soaring. This is the genus Propithecus of the family Lemuridæ.

In these forms the power of flight is somewhat limited. Flower and Lydekker give ten yards as the length of the leap, attributing the soaring to the powerful hind limbs, without even mentioning the existence of the patagium. Beddard on the other hand speaks of the "parachute-like fold of skin between the arms and the body which suggests the more complete parachute of Flying Foxes, etc."

Propithecus includes three species, all from the Island of Mad-

agascar. They are diurnal, contrary to the general rule among volant mammals, though they prefer the morning and evening for their periods of activity.

SUMMARY

1. Volant evolution has occurred seventeen times among vertebrates, ten of which are merely adaptations for more or less prolonged soaring leaps, while in seven instances in all probability true flight has been developed.

2. Soaring implies, with but one exception, the development of a fold of skin along the creature's flanks supported in one instance by the extension of the ribs beyond the body wall, but generally stretched between the fore and hind limbs. This fold is often supplemented by others in front of the fore limbs and between the hind limbs sometimes involving the tail.

3. True flight always implies a more or less profound modification of the fore limbs which become, as a consequence, unsuited to ordinary progression. True flight has been developed once in each of the classes of strictly air-breathing vertebrates, and probably at least four times among fishes.

4. With the exception of the fishes, soaring implies also present or ancestral arboreal adaptation and this may apply as well to the true fliers. It is certainly true of the bats, possibly true of the birds, but of the pterodactyls one cannot be certain.

5. Besides the primary modifications which constitute the machinery of flight, other portions of the body, especially the nervous system, the sense and the nutritive organs, may exhibit secondary volant characteristics. These, as with the primary modifications, are in direct proportion to the powers of flight.

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EXTERNAL MORPHOLOGY OF THE DUGONG

H. DEXLER AND L. FREUND

In continuation of our previous article in this journal on the physiology and biology of the dugong, we wish now to treat of its external morphology. Present knowledge of this subject is indeed considerably greater than that of its biology though it is still far from complete and particularly has the want of a good figure of the animal been felt. Kükenthal was keenly sensible of this and sought partially to remedy the defect by giving an excellent figure of a dugong embryo and its snout. It is our hope that the figures here given will at least in some degree make amends for this lack of illustrations, since they are from photographs taken by Dexler on the Australian coast during an expedition for the purpose of obtaining dugong material for scientific study, supported by the Gesellschaft zur Förderung deutscher Wissenschaft, Kunst, und Literatur in Böhmen. It is instructive also to compare these photographs with the first sketches of the dugong drawn from Nature by Dr. O. Finsch (*Illustr. Zeitung*, Leipzig, 1901, no. 3012). The description as well, is capable of improvement and amplification, for otherwise there would have been no object in obtaining the material.

As regards the size of the dugong, various measurements were made of several specimens killed and these measurements are here brought together in the following table.

Table of Measurements in Centimeters

No. and Sex	7♂	1♂	2♂	4♀	5♂	6♂	7♂
Total length	273	315	311	245	280	290	300
Greatest girth (hand's breadth behind flippers)				202	181	200	
Axillar girth						175	183
Breadth of caudal fin				77	82		77
Length of flipper				28	32	36	34
Breadth of flipper						20	22

No. and Sex	7♂	1♂	2♂	4♀	5♂	6♂	7♂
From eye to end of snout				18			
From eye to ear opening				15			
From anus to center of margin of tail				80	82		101
From genital opening to center of margin of tail				90	132		156
From navel to center of margin of tail					169		191
Interorbital width				21			
Width of snout				24	22		
Height of snout					17		
Depth of mouth cavity				10			
Palatal process (breadth: height)					7.4		
Extent of lung sounding (from tip of snout)					160		

From these measurements it is seen that the smallest specimen was a female, 245 cm. in length. The male animals obtained, measured from 280 to 315 cm. in length, and of these the two measuring 311 and 315 cm. respectively, were the largest of 25 dugongs captured. The published records of the size of these animals show some variation. Turner and Finsch have already pointed out that the older authors were wrong in placing the average length of the dugong much too high (*e. g.*, Brown, 20 feet), and indeed all the measurements examined show (*cf.* Raffles, Owen, Rüppel, Klunzinger) that the dugong does not exceed 3½ meters in length (see also Finsch). In this, Rapp (8 to 10 feet) and Fairholme likewise agree. The statement of Brehm, 3 to 5 meters, is thus somewhat exaggerated. The length of the female is generally given as slightly less, and in our specimen was 2½ meters (Owen, 2.23 m.; Klunzinger, 2.37 m.).

As to the color of the dugong, Finsch has previously written at some length, and has brought together the various expressions that have been applied to this elusive shade. His account and that of Gill appear to agree with our own observations, namely, that the dorsal surface is in general a light grayish brown to bright bronze-brown with a slight metallic shimmer, while the ventral side is white to bright gray. According to Finsch the younger animals are almost bright flesh-color. The color of the dugong of the Red Sea has been otherwise described (by Rapp, Rüppel, Brehm) as a dull lead-gray, the back and top of the head more greenish. The dugong embryos from Australia studied by Kükenthal were blue-black on the head and brown on the belly, and this

shade became lighter in larger animals. Brehm likewise mentions dark longitudinal streaks which, however, Kükenthal did not observe. Preserved skins become much darker with age until they are nearly black (Krauss, Finsch).

The skin is in general smooth, almost shining (Rüppel, Klunzinger, etc.). In case of animals that have been lying on the shore for some time, the skin, particularly of the dorsal side, shows an unusual luster. On the back and on the sides of the body there are numerous scratches and scars. These run in all directions, intersecting one another, and often are very deep, giving the animal a peculiar appearance. According to Klunzinger the dried skins show only a few scars but numerous furrows. Krauss also refers to the numerous scars and believes that they are due to injuries

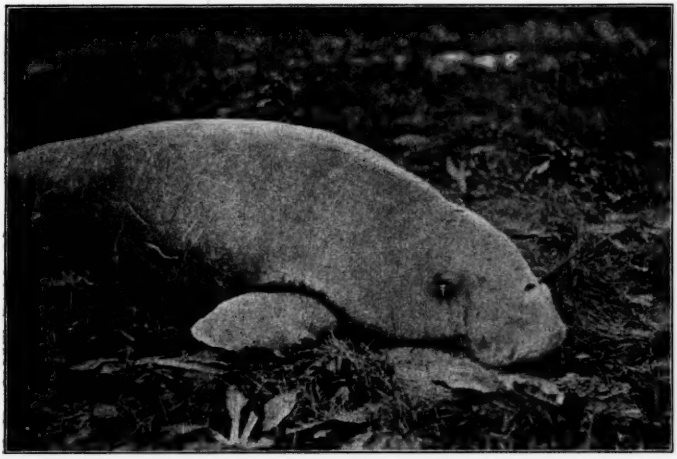

FIG. 1.— Australian dugong, antero-lateral view.

from contact with the coral rocks. The back and sides of the body are thickly studded with Chelonobiæ and less numerous Balanus. Finsch and Brehm assert that the skin lies everywhere smooth and is wrinkled on the stomach only. According to Rüppel there are a few small longitudinal folds on the sides of the belly. On close examination, however, we find that the skin is really not smooth throughout, but that there are numerous furrows

and wrinkles particularly on the head and fore part of the body. Thus many of them run parallel to each other from the corner of the mouth between the upper lip and the eye. Others pass below the eye, to radiate out from in front of it. Between the eye and the ear are many transverse folds which run toward the base of the flipper. The nuchal region is likewise traversed by wrinkles, among them a particularly prominent neck furrow. Many others are present in the region of the eye and will be described in connection with the latter. A deep surface furrow is present at the junction of the flipper with the body, while dorsal to this, a broad band of fine wrinkles varying in width passes to the eye. A few deep furrows traverse the neck ventrally and pass caudally into numerous longitudinal folds. The navel, genital opening, and anus lie in these longitudinal furrows which in the old males are deeper and more numerous. Behind the anus are a few transverse furrows on the side and these Kükenthal found in the embryos as well.

All over the body in little pits stand the hairs, some of which are living, others dead. They are short and slender yet stiff bristles, and may readily escape notice on account of their distance

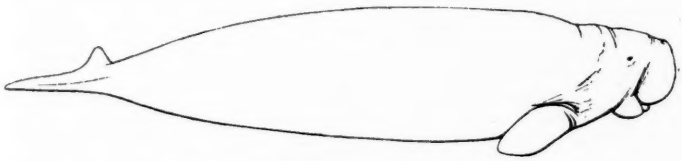

FIG. 2.— Dugong, lateral view. From sketch by Dexler.

from one another (Finsch) but by passing the hand over the back of the animal they may easily be felt. They are more numerous on the back than on the belly (Klunzinger). Their distance apart according to Krauss is from 0.5 to 0.8 cm., though these figures can hardly apply to an adult animal. For Kükenthal in an embryo the length of whose back was 72 cm., found the intervals between hairs to be from 4 to 8 mm. Rüppel gives the distance in adults as 1 inch, Brown as 1 to 2 inches, and according to our observations it is not much greater. In an embryo 162 cm. long, Küken-

thal found distances of from 2 to 3 cm. even at that early stage. This observer states particularly that there is a regressive development of the hairy covering in Sirenia such as he had shown previously to a greater degree in case of the Cetacea. Turner claims to have observed that the hairs were arranged in rows in an embryo dugong, but of such an arrangement we saw nothing. On the other hand, we found hairs, scattered to be sure, on the flippers and caudal fin where their occurrence is denied by Rapp, Rüppel, Brehm, and Finsch.

The body is in general spindle-shaped though not uniformly round as Rüppel and Brehm state. Anteriorly it diminishes in transverse diameter so that the head stands high, while posteriorly it decreases rapidly in vertical section till the body terminates in the horizontal caudal fin. The chest is somewhat trapezoidal in cross section in the middle, and toward the rear, with the decrease in width of cross section dorso-ventrally, it becomes flattened out laterally. The head is marked off by a shallow furrow at the neck. On the back the dorsal processes of the vertebræ are distinctly visible as low eminences all the way to the end of the tail as Owen has also shown. Rüppel noticed this feature in case of the tail only. The ends of the ribs also are evident along the sides of the breast.

The head of the dugong is the part showing the most modeling. The powerful curved upper mandible — compared by Brown to a nose of a very pronounced Roman type — the broad obtuse snout, and the nares situated on the summit of the head, give the latter a very characteristic appearance. We shall consider its peculiarities first through a study of the figures before going into the somewhat contradictory accounts in the literature of the subject. The head consists of a strikingly heavy skull and upper jaw and the small lower jaw almost lost to sight underneath it and separated from the cranium by the mouth cavity which slopes obliquely forward and downward. As before mentioned the head is marked off by a furrow at the neck. Ventrally, opposite the nape, a sharp clear boundary is made by a right-angled fold of skin. Seen from above, the head is longitudinally rectangular, considerably smaller than the neck, while the height of the head in side view is not greatly different from that of the neck. The top of the head

curves sharply down on each side to the eyes. Anteriorly, toward the nostrils this arching is very slight, corresponding with the decrease in width of this region. The crown of the head is without hair, whereas the remainder of the upper portion is set with transparent bristles, from 4 to 5 mm. long, that arise from dark-colored pits. The sides of the upper jaw fall away rather sharply from the summit of the muzzle, downward and forward. From the nostrils, which are situated high on the head, the anterior portion slopes at first gently then bends strongly down to the

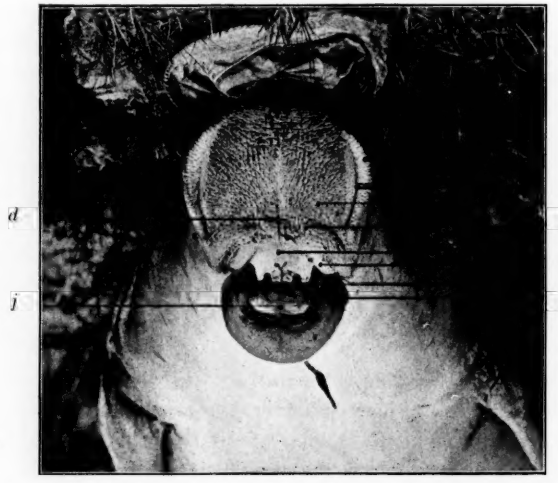

FIG. 3.— Dugong's head, anterior view. *a*, lateral fold; *b*, lateral furrow; *c*, central area; *d*, median furrow; *e*, lower limiting fold; *f*, mandible; *g*, intermediate fold; *h*, incisor tooth; *i*, chin fold; *j*, palatal process.

mouth, to form the remarkable surface of the snout which is peculiarly modified on its lower portions. This area is broadly horseshoe-shaped, somewhat convex anteriorly, with the point directed a little obliquely forward and downward. It is from 22 to 24 cm. broad and 17 cm. high.

In the living animal the snout is soft and flexible and consists of a solid muscle mass traversed by fatty tissue, wherein the fiber bundles intersect in a complicated fashion as in the tongue. The skin of the snout is so very delicate and pliable that it may readily

be gathered into a very narrow fold between the fingers. The surface of the snout is differentiated into (1) a middle portion, (2) its ventral posterior fold, and (3) the two lateral folds. The middle area is of the shape of a broad horseshoe. On its lower part there is a sharp median furrow which becomes lost ventrally in the gums, and likewise disappears in the dorsal third. The anterior half of this furrow is much shallower than the posterior. The entire surface is striated with numerous wrinkles which can be seen to have definite courses. Anteriorly, curves predominate whose convexity is forward while posteriorly there start on each side of the median line numerous wrinkles, at first parallel with

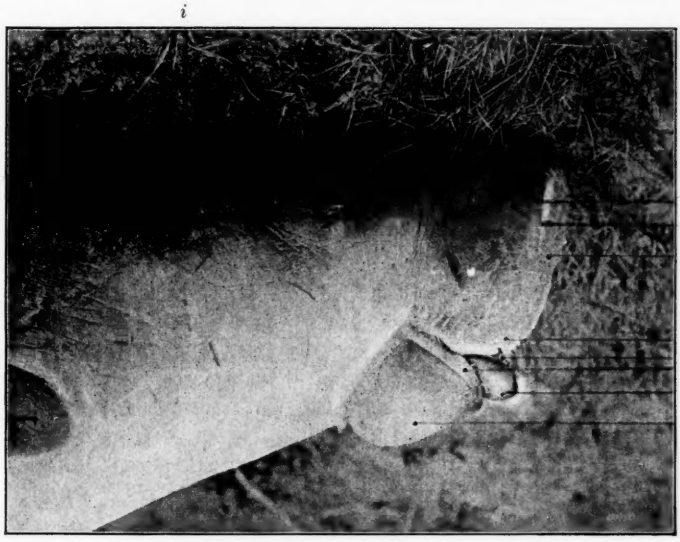

FIG. 4.— Dugong's head, lateral view. *a*, lateral fold; *b*, lateral furrow; *c*, central area; *d*, mandible; *e*, incisor; *f*, chin fold; *g*, palatal process; *h*, chin; *i*, ear; *j*, fold at the flipper; *k*, furrow at the flipper; *l*, flipper.

one another, that radiate out towards the sides and, running forward, cross those first mentioned. On the folds thus produced stand thick short bristles. Dorsally the median surface of the snout passes into that of the general integument of the anterior dorsal region.

The demarcation of this middle area posteriorly is effected on both sides by a low broad fold which is crossed by the median furrow but begins at some distance from it and, becoming better defined laterally, passes downward and backward toward the corner of the mouth. Then on both sides it passes into the side fold of the middle area. Opposite the mandible, relatively opposite the gums, the lower fold becomes greatly enlarged though in the figure this feature does not appear since the flabby snout of the animal as it lay on its back, has sunken down. Nevertheless there is visible in this position an intermediate fold on both sides which fills the space between the corner of the mouth, the lower fold, and the mandibular process. The posterior limiting fold is likewise thickly set with the bristles previously mentioned. The middle fold, particularly toward the furrow, also shows these stiff, backwardly directed bristles.

The lateral folds are comparatively small and are separated from the middle area by a deep indentation. In the figure, these furrows gape apart on account of the depression of the snout. Numerous transverse wrinkles that intersect on the inner and outer sides, as well as an abundance of bristles along the borders are present on these lateral folds. They begin rather well up toward the dorsal part of the snout, and with a gentle lateral sweep, enclose the middle area and with a strong curve pass posteriorly toward the corners of the mouth. Here they merge with the posterior fold and at the same time the limiting furrow becomes very shallow. Beneath the snout and completely hidden by it when in the normal position, is the mandibular process covered by the gums. In the male this process bears on each side a short but stout incisor. The gum has a median anterior groove. Below the end of the mandible and the points of its projecting teeth is a strong firm palatal process that consists of solid fibrous tissue and reaches beyond the incisors. It is about twice as wide as thick (7 cm. to 4 cm.) and with its rounded anterior end bears a certain resemblance to the tip of a tongue. It is not retractile and is clearly visible between the jaws even when the latter are closed. From the fact that the furrows made in the sand by the dugong in grazing are of the same width as these palatal processes, it may be concluded that they play a part in the taking of food.

The shortened lower jaw is directed diagonally downward and extends backward with a breadth corresponding to that of the narrow mandibular cavity which is but 10 cm. deep. The anterior portion of the lower jaw is narrow and becomes rounded at the tip so that not only is it well set off from the neck but the angles of the mouth are also strongly drawn in. The transverse diameter of this chin-like projection is considerably greater than its length.

FIG. 5.— Dugong's head, ventral view. *a*, lateral fold; *b*, lateral furrow; *c*, central area; *d*, median furrow; *e*, palatal process; *f*, chin fold; *g*, chin.

The greatest length is in the plane of the mouth, for as is seen in profile, the outline of the chin starting from its origin at the neck, constantly recedes from the mouth till it bends down again to the tip of the jaw. The greatest transverse diameter is about in the middle between the corners of the mouth, along the line marking the origin of the chin from the neck, for the line defining the chin posteriorly is bent down on each side toward the corners of the mouth, like a pair of tongs. Along the margin of the mouth on

each side of the lower jaw is a low narrow ridge which is marked off by a slight furrow from the rest of the chin. This ridge as well as a broad adjacent strip of the chin is thickly set with short fine bristles. The remainder of the surface of the chin bears coarser and more scattered bristles each of which springs from a small dark pit, just as in the case of the fold at the edge of the mouth near the palatal process.

In reviewing the literature on this subject we will first consider the account given by Rüppel. Contrary to our observations, he states that the long median furrow of the snout is bifurcate ventrally so that its form is that of an inverted Y. By this bifurcation, this portion of the snout is divided into three parts, the two upper of which belong with the nose while the small lower triangular part forms the upper lips proper, directed toward the inner surface of the mouth. It is of course obvious that the long vertical furrow spoken of by Rüppel is identical with that described by us. The bifurcation which, as our description shows, has nothing particular to do with the median furrow, is the bow-shaped depression formed by the snout proper and the palatal process. The small three-cornered portion below is the palatal process, which of course has no connection whatever with the lips. Rapp speaks in only a general way of the Sirenian snout. He states that the upper jaw ends anteriorly in the form of a flat blunt disc richly provided with nerves, that perhaps functions as an organ of taste; and further, that in the case of the dugong particularly, the "lips" are very thick and they as well as the corners of the mouth toward the inner side of the cheeks bear thick stubby bristles. Krauss makes no mention of the median furrow of the snout but describes the side folds which Rüppel omits. Both authors give detailed accounts of the distribution of hair on the snout. Krauss, however, correctly describes the palatal process and the fold at the edge of the lower jaw. Brehm and Finsch make mention of the head in a few words as does also Owen who considered its peculiar form to be especially adapted for the taking of food. Turner gave an extended account of the head of an adult female dugong but a comparison of his figure with ours shows that the preservation of his specimen with dry salt must have been very poor for it is greatly shrunken and out of shape. In consequence, the descrip-

tion based on this specimen can be only partially followed. For the median furrow is brought into connection with the furrows between the middle area and the posterior limiting folds as if it were bifurcate. The side folds end in a point posteriorly and are not continued into the posterior fold, which instead comes from the lateral portions of the middle area (Figs. 3, 5). Turner describes the greatly shrunken palatal process in his specimen as "middle lip (mesial process)" notwithstanding that it has no genetic connection with the lips. The middle area, on account of its being cut by the median furrow, is misleadingly called "lateral lips," so that in considering the homologies of the parts mentioned, it is necessary to take into consideration the probable shrinkage that they have undergone.

Of particular interest, naturally, are the embryological conditions as pictured in Kükenthal's sketches of a freshly preserved fetus. These sketches are much more satisfactory than the figures of the fetus given by Turner. In all the embryos the deep median furrow of the middle area is apparent. In his fourth stage, Kükenthal was able to make out a shallowing of this furrow in the region of the lip. From the fact that this portion of the furrow was lacking in Turner's figure of the adult, Kükenthal concluded that a fusion had here taken place between two originally separate portions in such a way that the two lateral parts of the upper lip had become united medially. In further support of this view, he cited Rüppel's figure, which as we have shown above is to be otherwise interpreted and is thus unavailable as evidence on this point. In our specimen the median furrow extended to the gum, and, since Turner's figure is untrustworthy, it can hardly be held that the two portions of the middle area are united at the posterior part of the furrow. At the same time we do not wish to contest Kükenthal's conclusion that the snout of the dugong, which in the adult is rather simple, has become like that of the manatee through a division into a median area and two lateral areas and that thus the manatee's snout is phylogenetically the older. For with this conclusion we are in hearty sympathy. This third median portion is to be found at the upper end of the median furrow as indicated by its upper bifurcation in a fetus of 72 cm. (Kükenthal), and an almost horizontal bifurcation in a fetus of 162 cm. in length (Tur-

ner). At an early period the two lateral folds are formed and are marked off in the embryo by a lateral furrow which is wanting in the adult, or is apparent in certain places only (Kükenthal). The side folds, which at first converge dorsally in the embryo, later become parallel, and finally in the adult become divergent above. The growth in breadth of the middle area is correspondingly greater in its upper than in its lower portion. The two posterior limiting folds of the middle area appear to be formed later. They are figured by Kükenthal from an embryo 162 cm. long. In the embryo the surface of the snout is marked off into little spaces with a beautiful regularity and from the center of each knob-like space rises a hair. The form of the palatal process and of the lower jaw in the embryo is not greatly different from that of the adult.

A short distance above the snout are the blowholes. These are two almost circular openings, close together and directed obliquely upward and forward on the muzzle. Owen characterizes their high dorsal position on the curve of the intermaxillary as one that is very advantageous for breathing. In our figures the nostrils are open, as usual in dead specimens. When the nostrils are closed, the muzzle is arched forward and slightly rounded. In our specimen we found nothing that might be called a valve-like structure, such as Rüppel and Turner mention, but this subject we have treated at length in our previous paper as regards both the dugong and the manatee (*Amer. Nat.*, vol. 40, pp. 49–72).

The eyes are situated on the side of the head, 18 cm. behind the tip of the nose in specimens of average size, and are about equidistant from the end of the snout and the corners of the mouth. They are visible through a narrow spindle-shaped opening that slants obliquely upward, and is 12 mm. long (Owen also). The eyelids are thick and tumid, and only feebly movable up and down; they are provided with a contractile muscle, the musculus orbicularis oculi. At the anterior corner the nictitating membrane is clearly visible (*cf.* also Rapp and Owen). There is no trace of eyelashes although Brehm speaks of them regardless of Rüppel's correct assertion that they do not exist. The bulbi are small and nearly spherical, though not egg-shaped as Brehm states. The iris and choroid layer are black-pigmented so that the whole eye appears dark.

In the region where the head passes into the neck, there is on each side of the former, at the end of a transverse series of neck furrows, the small ear opening. This is in a scarcely noticeable depression of the skin about 3 mm. in diameter, at about the same level with the eye and some 15 cm. behind it. There is no external ear and Turner found none in the embryos.

The external form of the two pectoral appendages, which arise not far from the head toward the ventral side of the body and project laterally, has been rather exhaustively treated in a work on their osteology by Freund. It remains to say, however, that the flippers are usually directed backward along the sides of the body, so that a thick fold arises above the furrow at the insertion. The upper surface is darker than the lower. The absence of hair on the flippers has already been mentioned. In the adult animal, the extreme length of the flipper is not over 32 cm., and the greatest breadth is 20 cm. or a trifle more.

The mammæ are short, hard, cone-shaped structures as thick as one's thumb. They are situated, one on each side, in the axillary region, behind the furrow of the flipper, as Owen and Rüppel also state, and are seen well from the ventral side. According to Owen, their bases in the case of a female specimen were about the size of a shilling, and they rose about one half an inch above the surrounding surface. Turner found no trace of mammæ in an embryo 162 cm. long.

As to the rest of the body there is but little to be said on account of the few peculiar characters it possesses. In the middle of the belly is the navel and 40 cm. behind it is the preputial opening or the vaginal furrow as the case may be. The latter is a slight cleft about 10 cm. long (*cf.* Klunzinger also) and is hardly to be differentiated from the anus. It lies slightly nearer the middle of the tail — 90 cm. (100 according to Klunzinger) — than the penis which is from 132 to 156 cm. distant from the navel. On these points Bischoff has published some observations. The anal opening and the vagina are closer together than are the penis and the anus. In animals that have been dead in the nets for some time and in which decomposition has begun, the penis is usually prolapsing. It is covered by an unpigmented skin and ends in a conical point with two large lateral lips.

The caudal portion of the body consists of a horizontally flattened fin, with a very slight indentation at the posterior margin. Its breadth is from 77 to 82 cm., and on this point Raffles and Owen also agree. There is no indentation in the shape of a half moon such as Rapp, Rüppel, and Brehm mention, but the posterior margin is feather-edged and often is considerably torn. According to Owen the tail is relatively larger than in the whales, and this he explains as due to the frequent necessity for coming very quickly to the surface for breath while feeding.

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REPRODUCTION OF *METRIDIUM MARGINATUM* BY FRAGMENTAL FISSION

M. L. HAMMATT

DURING the autumn of 1897, a specimen of *Metridium marginatum*, about one half an inch in diameter at the base, was kept by the writer for some weeks in a glass jar in an open north window. Its favorite resting place was near the edge of the sea water, where it could be plainly seen both from above and through the side of the glass. One morning it was noticed that its tentacles were withdrawn, that it had evidently moved toward one side, and that whereas the night before its basal outline had been quite regular, it now showed a slight inward curve, opposite to which, at a short distance from it, was a fragment which had evidently been divided off during the night. The separation between the two was not quite complete, as a transparent thread passed from one end of the fragment to the parent form, disappearing, however, soon after. The distance between the two was gradually increased and the fragment was seen to possess life, because it changed shape from time to time.

This fragment was carefully watched for a few days and was seen to curl together gradually until its extremities met, but the opportunity for following its further development was wanting.

Later on it was discovered that this reproduction by fragmental fission in Metridium was mentioned by Verrill in an article entitled "Our Common Sea Anemone" in the second volume of the *American Naturalist*, also that similar reproduction in *Anthea cereus* was noted by Gosse, in *Sea Anemones and Corals*, 1860 (page xxi of the introduction and page 169), and in Tenby, where he states, on page 373: "If the body be torn away and only a portion of the base remain, from this fragment a new offspring will sometimes

rise up to occupy the place of its parent." Dicquemare and Dalyell also observed the same mode of division in sea anemones.[1]

When the observation of the writer as above recorded was mentioned to Professor A. Hyatt, he remarked that reproduction by fragmental fission in *Metridium marginatum* had not, to his knowledge, been thoroughly studied and figured, and suggested the advisability of pursuing the investigation further with a view to publication, adding that a series of drawings illustrative of the process observed would be of value as an aid in the teaching of asexual reproduction. In accordance with this suggestion and in the hope of ascertaining whether forms thus produced developed later into whole organisms, more small specimens of the same genus were collected in June, 1898, in the same tidepool from which the former Metridium mentioned had been taken. This tidepool was a small one and in it, especially along the edge, under the overhanging seaweed, the Metridia were numerous. Fragments were sought for and readily found in abundance not far from the mature forms. These were in various stages of the process of curling together and obviously had been produced by fission similar to that already observed within doors. One of these fragments which was larger than the others had partly curled together and on the next day the ends had come in contact and two tiny prominences, apparently the beginnings of tentacles, had appeared.

On examination of this same tidepool at various times since then, like fragments have always been found. They showed generally neither tentacles nor mouth, and their irregular, elongate shape, not having taken on the radiate form, also their brownish color,

[1] Since writing the above paper, my attention has been called to A. Andres' publication "Intorno alla scissiparita delle attinie," (*Mitteil. Zool. Sta. Neapel*, vol. 3, pp. 123–148). My observations were made without any previous knowledge of those of Professor Andres or of any other naturalist. They were also made on a different species. Moreover, my figures show three points not illustrated by Professor Andres, or to my knowledge, by any other authority: first, oral views of successive stages of development of the young produced by fragmental fission (laceration) showing the *completion* of the curling process by which the young assumes the parent form; second, serial, transverse sections of parent and young in process of fragmental fission showing the infolding of the body wall preceding the separation of the two; third, diagrams illustrative of the process of such fission.

distinguished them from the transparent young developed from the ovum.[1]

The Trembley experiments previously performed on the hydra suggested the pursuance of the same method with *Metridium marginatum*, hence on Wednesday, June 15, 1898, at 2 P. M., the fragment figured at Plate 1, Fig. 1, was produced by artificial fission from the base of a specimen one fourth of an inch in diameter. The Metridium threw out one acontium near the mouth and several where it was cut, and drew in its tentacles entirely. When cut off the fragment fell to the bottom of the glass as if it were without life, and had to be turned over with a needle so as to rest on its base. This fragment was kept under careful observation every day for a period of three weeks and, from studies taken from time to time, the accompanying drawings were made.

The lines crossing Fig. 1 (Pl. 1) nearly at right angles to its length represent portions of the radiating mesenteries of the parent form as seen through the body.

At 2.15 P. M. of the same day the Metridium had extended its tentacles, and in the fragment, as seen in Fig. 2 (Pl. 1), the extremities were approaching each other.

Fig. 3 (Pl. 1), drawn at 4.30 P. M. of the same day, shows a nearer approach of the ends and a difference in size, whether due to growth or to the re-assertion of the power of expansion possessed by the normal animal.

In Fig. 4 (Pl. 1), drawn Tuesday, June 21, at 2 P. M., is seen a greater elevation of the column and a more spreading base, although the ends have not yet joined.

In Fig. 5 (Pl. 1) drawn on Wednesday, June 22d, at 10 A. M., the extremities of the fragment have come together, thus producing, approximately, the normal radiate structure of the sea anemone, leaving, however, a slight inward curvature at the point of junc-

[1] Since the above observations were recorded, a number of these fragments, already beginning to curl together, have been carefully collected and placed in a jar where the successive stages leading to their maturity have been followed. They have been found to develop in essentially the same way as did the artificially produced fragment described farther on. The ends of one unusually long fragment curled in opposite directions. Could this latter suggest the origin of many of the double-mouthed Metridia found?

ture. The base here is a trifle more extended and the column, as shown in Fig. 6 (the side view of Fig. 5), is much more elevated.

On Thursday, June 23d, at 11.30 A. M., Fig. 7 (Pl. 1) was drawn. Here the young form shows translucent prominences afterwards recognized as the beginnings of tentacles, the one at the line of juncture being less developed than the others. This line of juncture is still visible up as far as the tentacles and makes a slight irregularity at the base. The mouth could be discerned but faintly at this time.

Fig. 8 (Pl. 1), the side view of Fig. 7, shows the tentacles more plainly.

Fig. 9 (Pl. 1), represents the young form as it looked on Saturday, June 25th, at 3 P. M. It shows a further development of tentacles and mouth and an increase in size.

In Fig. 10 (Pl. 1), the side view of Fig. 9, the line of juncture is seen to have disappeared throughout the upper third of the column. In Fig. 11 (Pl. 1), drawn on Saturday, July 2d, the hour not noted, this line is still fainter and shorter and a further increase in the size of the animal is indicated. At this time the young Metridium was very active, crawling along the glass at the edge of the water. Ten tentacles were visible, unequal in size. Lack of symmetry is especially noticeable here and in the following figure. This same lack of symmetry holds in all observed forms which were produced by fragmental fission. Whether these forms ultimately become symmetrical is not known to the writer.

Fig. 12 (Pl. 1), was drawn on Wednesday, July 6th, just before the young Metridium was put into formalin. This shows a further growth and a development of two more tentacles, making twelve tentacles in all.

Thus in the three weeks, from Wednesday, June 15th, to Wednesday, July 6th, a fragment from the base of a small *Metridium marginatum* curled together until its extremities met, developed a spreading base, a column, twelve tentacles, and a mouth, and must therefore have performed the nutritive functions, as evidenced also by the increase in the size of the animal. This experiment of artificial fission was repeated several times on other Metridia with similar results.

During the examination of microtome sections of small Metridia

at about this time, for the purpose of studying the microscopic structure of the animal, one Metridium revealed the serial sections figured in Plate 2. These figures are slightly diagrammatic, as intended to illustrate merely the point under consideration. From a study of these sections, if the above observation of reproduction by artificial fragmental fission be borne in mind, the inference may be drawn, that at the time of killing, the Metridium from which the sections were taken was preparing to reproduce asexually by cutting off a fragment.

In Fig. 1 (Pl. 2), either the cutting was not parallel to the oral disc, or the column was unevenly distended vertically, as the tentacles are seen on but one side, that opposite to where fission takes place. This is also noticed in sections shown in Figs. 2 and 3 (Pl. 2). The same fact was noted in regard to similarly placed serial sections of other Metridia examined, which were reproducing in the same way.

In Fig. 1 (Pl. 2), the uppermost in which fission is visible, the separation between parent and fragment is seen to be complete. Portions of the old mesenteries reaching from the outer to the inner body wall are visible in this section in the young.

In Fig. 2 (Pl. 2), the fragment cut off is longer than in section 1, but the separation between the two is not quite complete.

In Fig. 3 (Pl. 2), the infolding of the body wall which makes the division between parent and fragment is not continuous as in sections 1 and 2. The break is seen toward that extremity of the body where the tentacles are visible. This break in the continuity of the fold in the section may be due to a slight irregularity in the folding. No separation between parent and fragment, such as was seen in sections 1 and 2, has as yet taken place. The fragment here cuts off a greater proportion of the parent body than in the section before considered. It is also wider and shows longer mesenteries. Bilateral symmetry is here evident in the parent after the infolding of the body wall which is to cut off the fragment. This same fact is noticed in sections of other Metridia in which like fission is taking place.

In Fig. 4 (Pl. 2), the dividing fold is seen pushing inward from either side, evidently about to cut off here a still larger proportion of the parent than in Fig. 3. It will be noticed here, where the

ends of these folds are as yet far from meeting that, previous to fission, there has been an increase in size on the side where this is to take place. This seems to be in accordance with the general rule that extra growth usually precedes fission.

Fig. 5 (Pl. 2), shows the folding of the body wall extending inward but little from either end. One of these folds shows new mesenteries growing from the side which is to form the inner surface of the body wall of the parent. In this section the fact is still more apparent that, before fission occurs, the parent form lacks bilateral symmetry and that the division takes place on the larger side.

The same is seen in Fig. 6 (Pl. 2), which shows only the beginnings of the inward foldings of the body wall, after the completion of which the parent form is to be approximately symmetrical.

In the other sections between that shown in Fig. 6 and the base or pedal disk, the same conditions hold with regard to lack of symmetry as related to the side upon which fission takes place. The body wall shows no inward folding here, but judging from the artificial and natural fission observed, the folding would eventually have reached the base.

In all the sections shown, the line *a. b.* passing between the two pairs of directive mesenteries, *d. m.*, represents the plane of symmetry of the parent animal. The fragment is seen to be divided off on one side only of this plane.

The study of serial sections of other Metridia showed the complete and the partial infolding of the body wall essentially like the above, and evidently preceding fragmental fission.

In consideration of the facts as observed and stated above, the following conclusions are reached by the writer as to asexual reproduction in *Metridium marginatum* by fragmental fission. This occurs in nature as observed in the jar within doors and as seen in the tidepools; also as indicated by the sections. It occurs frequently, as shown also by observations on tidepools.

From the study of sections it is inferred, that the body becomes bilaterally asymmetrical before fragmental fission takes place, this occurring always, as far as observed, on the larger side and that the fragment thus cut off includes body wall (formed on the side next the parent by infolding of the parent body wall), and

parts of directive and other mesenteries on one side only of the plane of symmetry of the parent animal. The sections show also that the infolding of the body wall proceeds gradually, and simultaneously downward and inward from the top and upper part of the sides, and that separation of the fragment from the parent commences at the top, as indicated by diagrams (Figs. 7 and 8, Pl. 2).

This infolding of the body wall here, to separate the fragment from the parent form, seems to be essentially the same process as the constriction which divides the Hydra bud from its parent, but here the basal attachment modifies the process by preventing the infolding on that side and by keeping the fragment close to the parent until separation is complete. Whereas in Hydra, a thread tied between parent and bud would represent the method of division, in Metridium the thread may be imagined as held down at either side of the pedal disk and gradually tightened along the line which is to separate parent from fragment, thus producing an infolding proceeding downward from the top and inward from the upper part of the sides.

Observations of the young naturally and artificially produced by fragmental fission show that the fragment cut off curls together until its extremities meet, making parts of mesenteries before nearly parallel now radial in arrangement, thus attaining to the sea anemone structure with the least possible expenditure of energy. From artificial fragmental fission principally, it is seen that the base or pedal disk spreads for attachment, the column becomes elevated, the line of juncture tends to disappear, mouth and tentacles develop, and growth in volume apparently takes place; that the young thus produced, possesses the power of locomotion and that it is, in fact, a whole organism, and, except for the fact that it has not yet attained symmetry, is essentially, in outward appearance at least, a smaller reproduction of its parent.

Obligations are due to Dr. A. G. Mayer for reading this paper, to Mrs. J. M. Arms Sheldon for valuable suggestions, and to Professor G. H. Parker for the determination of specimens; also to the artist, Mrs. A. M. Dodge, for faithful delineation of specimens and sections.

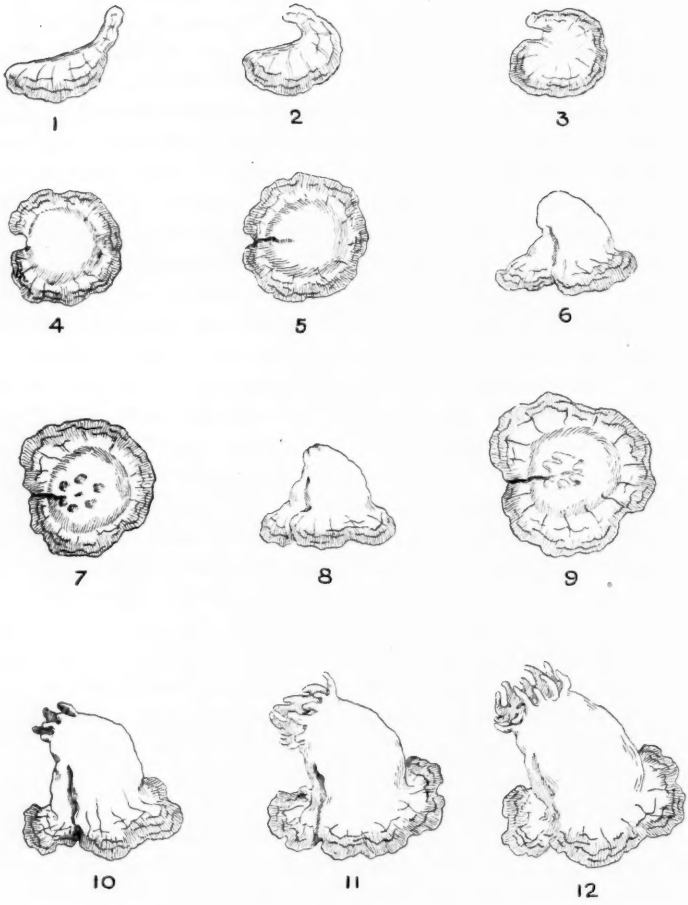

PLATE 1.

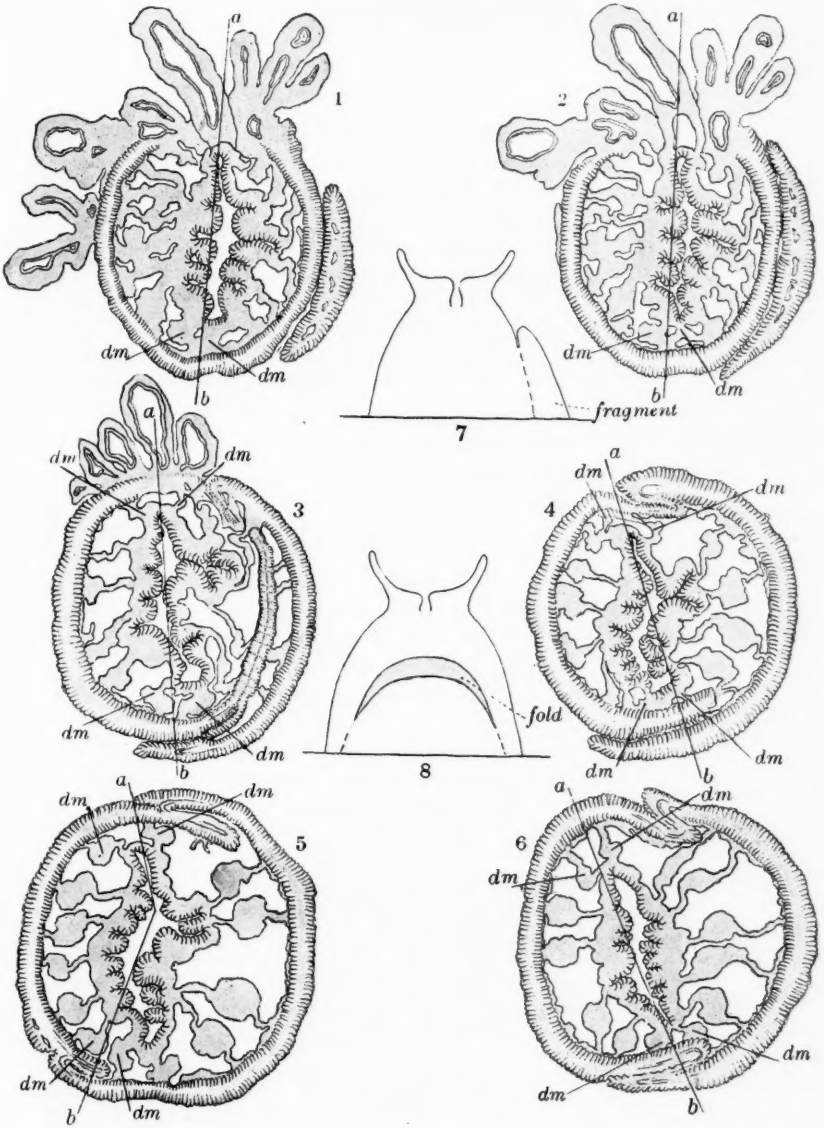

PLATE 2.

NOTES AND LITERATURE

ZOÖLOGY

Plankton of Northern Seas.[1]— The earlier parts of this series of monographs (see this journal, vol. 39, p. 341) have been supplemented by two additional sections containing six more papers dealing respectively with the pelagic annelids, chætognaths, Rotatoria, Acantharia, Radiolaria (Acanthometrida), diatoms, and a portion of the pelagic eggs and larvæ of the fish of northern seas, that is of water north of 50° N.

The papers on the pelagic annelids and the chætognaths are necessarily brief, the former including only nine, and the latter but seven species. Dr. Strodtmann follows Krumbach in making use of the grasping teeth of Sagitta as diagnostic characters for specific distinctions. The pelagic rotifers are somewhat more fully treated by Dr. Lauterborn. As yet the marine rotifers are very incompletely known, except in the Baltic and North Seas. Only sixteen marine and brackish water forms have as yet been found in northern waters. About forty additional species of fresh-water rotifers are known to enter the seas but they are adventitous and do not become acclimated to the marine habitat, except in a few cases, in which marine varieties of fresh-water species are known, as for example in *Anuræa aculeata* var. *platei*, and *A. cochlearis* var. *recurvispina*. The marine species are all coastal or brackish-water forms, none being known as yet from the high seas.

Dr. Popofsky's monograph of the Acantharia (sublegion Acanthometra) will be especially welcome as it embodies the revision which he has recently completed of this group, the first to be made since the publication of Haeckel's monograph of the Radiolaria. The author

[1] *Nordisches Plankton.* Herausgegaben von Prof. Dr. K. Brandt und Dr. C. Apstein. *Dritte Lieferung.* M. 10. X. Anneliden, J. Reibisch, 10 pp., 15 figs.; Die Chætognathen, S. Strodtmann, 8 pp., 11 figs.; Nordische Plankton, Rotatorien, R. Lauterborn, 25 pp., 17 figs. XVI. Die nordischen Acantharien. I. Teil and Nachtrag, A. Popofsky, 27 pp., 20 figs. XIX. Diatomeen, H. H. Gran, 146 pp., 178 figs. *Vierte Lieferung.* M. 10. III. Eier und Larven von Fischen, I. Teil, E. Ehrenbaum. Kiel und Leipzig, 1905, large 8vo. 216 pp., 82 figs.

takes a justly conservative ground in the matter of species in this group and is much inclined to question the reported occurrence of certain forms in northern waters. He notes the solubility of the skeletal structures (calcium-aluminium silicate or hydrate) in acids, alkalis, sea water, or distilled water, and rejects species founded on "skeletlos" specimens.

Professor Dr. Gran's treatment of the diatoms of the plankton will be most welcome to all planktologists, for no comprehensive monograph of these organisms has appeared since that of Castracane in the *Challenger Reports*, and this unfortunately is far from complete. The more recent investigations, especially of Schütt and Cleve, have added greatly to our knowledge of the pelagic genera, but this revival of interest has been attended by considerable duplication and confusion in synonymy. The author's wide experience with these organisms makes his critical monograph most timely. The monograph includes nearly 300 species, most of which are figured. Excellent keys to both genera and species are found throughout the paper. It is perhaps desirable that the chromatophores should be more completely utilized in the description of species and that their position in the cell should be interpreted with reference to the vertical distribution in the sea and consequent exposure to light.

The first section of Dr. Ehrenbaum's account of the eggs and larvæ of the northern fishes found in the plankton includes nearly ninety species from about thirty families ranging from the Labridæ to the Pleuronectidæ. Although it does not include some families of greatest economic importance in northern seas, as for example the Clupeidæ and Gadidæ, this first part nevertheless contains much of interest along economic and fish-cultural lines. The young of nearly all, and the eggs and larvæ of many fishes are taken in the plankton. The pelagic habit is, however, of little systematic significance since the young of species of the same genus are in some instances pelagic, in others benthic in distribution. The author notes the significance of dimensions and pigmentation as diagnostic characters of the young and urges the importance of the examination of living material. Preserved eggs and larvæ, even in the best condition, are not readily determined. The size of the eggs, and of the characteristic oil globules, and the number of fin-rays, and to a less extent the number of vertebræ, are subject to considerable variation. It is noteworthy that the range of this variation increases with the area of distribution of the species, and with the length of the breeding period under observation.

The author's account is abundantly illustrated with over three

hundred figures many of which are original. The excellent work of the Helgoland Station is evident on many of the pages of this comprehensive report.

The authoritative character of the papers in this series insures for them a wide range of usefulness and a permanent value to all naturalists who are concerned with the pelagic life of the sea.

C. A. K.

Notes on Pennsylvania Fishes. *Notropis cayuga Meek.*— Early in August of 1904 I secured a single example of this minnow in the Allegheny River, above Port Allegany, in McKean County. This is, I believe, the first record within our limits. Other fishes noted from this locality were *Lampetra wilderi, Salvelinus fontinalis, Campostoma anomalum, Semotilus atromaculatus, Leuciscus elongatus, Rhinichthys atronasus, Catostomus commersonnii, C. nigricans, Erimyzon sucetta oblongus, Schilbeodes insignis, Esox vermiculatus, Ambloplites rupestris, Eupomotis gibbosus, Micropterus dolomieu, Boleosoma nigrum,* and *Uranidea gracilis.* In the summer of 1899 I noted *Polyodon spathula, Campostoma anomalum, Leuciscus elongatus, Notropis hudsonius, N. whipplei, N. cornutus, Rhinichthys atronasus, Stizostedion vitreum,* and *Boleosoma nigrum* from streams near Cole Grove and other places along the Allegheny.

In the Susquehanna tributaries in Cameron County during October of 1905, I noted *Lampetra wilderi* (apparently this species though I did not see it myself), *Semotilus atromaculatus, Leuciscus vandoisulus, Brama crysoleucas, Notropis cornutus, Rhinichthys cataractæ, R. atronasus, Exoglossum maxillingua, Catostomus commersonnii, C. nigricans, Schilbeodes insignis,* and *Boleosoma nigrum olmstedi.* All these species occur near Emporium. *Notropis amœnus* occurs near Paradise, in Lancaster County, where I have received it from Mr. J. S. Witmer.

Mesogonistius chætodon (Baird).— The only place where I have found this sunfish in Pennsylvania has been in the basin of Mill Creek in Bucks County, near Bristol. It seems to occur sparingly, and most all of my examples were secured in the colder months. I have not found any previous definite records for Pennsylvania.

Boleichthys fusiformis (Girard).— I have only found this in the same locality as the former in our State. The first example was secured July 23, 1905, and on December 24 of the same year I found it very abundant. Though known from the lower tributaries of the Delaware in New Jersey, this fish has never before to my knowl-

edge been taken in Pennsylvania. The conditions where I secured my examples were similar to those found about Crosswicks Creek near Trenton, where the species is more or less abundant, though perhaps not so characteristic as in the lower lands. On the latter date *Anguilla chrisypa, Notropis chalybæus, Brama crysoleucas, Erimyzon sucetta oblongus, Esox americanus, Umbra pygmæa, Shilbeodes gyrinus, Aphredoderus sayanus, Enneacanthus gloriosus,* the above mentioned Mesogonistius, *Eupomotis gibbosus,* the above Boleichthys, *Aromochelys odoratus,* larval Desmognathus, Cambarus, larval dragon-flies, and hosts of Crustacea and shrimp, Gammarus, were also taken.

Enneacanthus obesus, contrary to Cope's statement that it is rare, is fairly abundant in southeastern Pennsylvania, though apparently local. I have received many living examples from the "Neck" in the lower part of Philadelphia.

HENRY W. FOWLER

Note on Muhlenberg's Turtle.—While spending a few days in late April with Mr. T. D. Keim in the region of Cedar Swamp Creek, Cape May Co., N. J., we observed a number of turtles about the fresh-water pools at the edge of the salt-marsh near Palermo. A single example of *Clemmys muhlenbergi* was found in this locality, a fact of some interest as the species does not seem to have been noted from southern New Jersey before. As an upland animal its distribution may be explained to some extent by the appearance of *Calopeltis obsoletus* at Stone Harbor, recorded by Mr. Witmer Stone in this journal for 1906, p. 166. In fact, most of the narrow strip on the Cape May County seacoast shows traces of upland life, the intervening cedar-stained streams presenting usually peculiar features. *Kinosternon pennsylvanicum, Chrysemys picta,* and *Clemmys guttatus* were abundant as noted in sequence. *Chelydra serpentina* and *Terrapene carolina* were also found, together with *Natrix sipedon, Thamnophis sauritus, Rana pipiens, Hyla pickeringii, Acris gryllus crepitans,* and *Bufo lentiginosus.*

HENRY W. FOWLER

ANTHROPOLOGY

The Bontoc Igorot[1] is a well written and abundantly illustrated contribution to the ethnology of this interesting branch of the Malay people. The work is the result of the author's eight and a half months' stay among the Bontoc and other divisions of the tribe. It embraces a geographical and a historical sketch of the Igorots, notes on their physical characters and pathology, and descriptions of their social life and organization, economic life, political life, war and head-hunting, æsthetic life, religion, mental life, and language.

The word Igorot means "mountain people." The several branches of the tribe occupy northern Luzon, north of the 16th degree of north latitude. They are estimated collectively at from 150,000 to 225,000. The principal dialectic groups are Tinguian, Kalinga, Bunayan, Isanay, Alamit, Silipan, Ayangan, Ipukao, and Gadan. The Bontoc Igorots are so called after their principal village and the province.

The Bontoc Igorot (represented at the Louisiana Purchase Exhibition in 1904) is "a clean-limbed, well-built, dark brown man of medium stature." The men average 1.60 m. (5 ft., $4\frac{1}{8}$ in.) in height and are prevalently mesocephalic and mesorhynic. They are never corpulent and seldom thickset, their bodies being generally well formed and symmetric. The hair is black and straight, and the eyes brown. The women average 1.46 m. (4 ft., $9\frac{3}{8}$ in.) in height and more among them show a tendency to brachycephaly. The detailed description reads much like that of the American Indian and it is remarkable how many of those pictured in the book approach types often seen among the Indians.

The people are very primitive and wear but little clothing. Their principal occupation is agriculture. They are industrious, the social life is lowly, marriages are monogamous. "The social group is decidedly democratic; there are no slaves." There are but a few vices. The religion is animism and spirit belief, with the idea of one god. In disposition the people are kind and not servile. They are trustworthy. They possess a good sense of humor. The children are bright and learn quickly. The author has the best hopes for the future of the people.

[1]Jenks, A. E. *The Bontoc Igorot.* Ethnological Survey Publications, Vol. I, Manila, 1905.

The work is full of interesting details. The illustrations are mostly reproductions of very good photographs. Possibly it would have been better if the 154 plates had been bound separately; it would make the book easier to handle.

The creditable volume of Mr. Jenks leaves the earnest desire that it may be followed by a thorough physical and physiological study of the same people.

A. H.

Notes.— *Origin of the Slavs.* A comprehensive article (Zaborowski, "Origine des Slaves," *Bull. et Mém. Soc. d' Anthrop., Paris*, ser. 5, vol. 5, no. 6, Dec., 1904, pp. 671–720), in which the well known author sums up his investigations. The original country of the Greeks, Umbro-Latins, Gauls, and Germanic peoples was treated of previously. All these groups do not appear in history at the moment of their separation from their proto-Aryan territory; but they can be followed nearly to the limits of this region.

The Greeks were the first to gain their historic possessions. Their migration is lost in the obscurity of time. They occupied, in all probability, a part of the territory northeast of the Adriatic, living in those neolithic villages characterized by abundance and great variety of artistic pottery, such as that of Butmir, near Serajewo, Bosnia.

The Umbro-Latins, coming from the northeast, can be well studied in the remains of their habitations known as *terramares*, in the provinces of Emilia and Marches, northeastern Italy. They were still at that time in close relation with the proto-Aryan people of the Danube.

The home of the proto-Gauls was adjacent to and partly blended with the proto-Aryan region. It was located, as is known with certainty, along the upper Rhine and upper Danube, and extended thence to more or less determined limits northward and eastward.

The original proto-German country the author places, on the basis of archeologic and even historic data, in the lands west of the Baltic, where these people lived since at least the neolithic period.

To determine the exact origin of the Slavs is more difficult. The earliest historic accounts show them already spread over vast spaces and over regions very distant from one other. The hypotheses that they came as they were from Asia, or were identical with the Saramates, are untenable. The most creditable sources all refer their origin to the Danube (especially lower Danube region). Their language, belonging to the *satem* group, could not have originated except

in the zone east of the proto-Aryan territory. The linguistic ancestors of the Slavs spread over the Danube basin when the Umbro-Latins and Greeks on one part and the Gauls on the other were drawing away from it, or had abandoned it. They came after these peoples.

It is now known that the Illyrians, Pannonians, Dacians, Moesians, and Gétes were all Slavs. Originally, the Illyrians appear to have been one of the proto-Aryan peoples, but this element among them was eventually displaced by that which is characteristic of the Slavs. The introduction of this new element is believed to have been due to the Paphlagonians, and to have taken place after the Trojan war, or during the twelfth century B. C. The Paphlagonians were the neighbors of the Cappadocians in Asia Minor, and related to the proto-Armenians and Medes. They aided Troy and after its fall are supposed to have passed to Thrace, adopted the language of the Thracians and Illyrians, and mixed with these. They were people of dark complexion, with a rather short nose and brachycephalic; and they cremated their dead. The first Slav political unit appears as the Venedes, or Venetes. This people penetrated to the northeastern regions of what is now Italy. Their type and in a few localities even the Slavonic language are still found in these regions. From this locality they spread, still many centuries before Christ, northward and northeastward, to Bohemia, to beyond the Carpathians, Vistula, Dniester, and up to the Baltic. They founded Vindobona (Vienna) and their name persists with modifications in a number of localities (and as a name of a Slavonic people, the Wends), to this day. Wherever they went up to the time of christianization (8th to 12th century of our era) they practised incineration of their dead, and theirs is the industry known in archeology as that of Hallstadt.

For many interesting details the reader must be referred to the original.

A. H.

BOTANY

Plants and Light.[1]—A paper of Professor Julius Wiesner, dealing with the quantitative and qualitative light-relations of plants, is of particular interest to American botanists, since it records the results of observations made in the United States.

Some twelve years ago, Professor Wiesner, who fills the chair of plant physiology at the University of Vienna, led by his studies on the relation of light-intensity and heliotropism on the one hand, and that of light-intensity and carbon-assimilation on the other, inaugurated a series of observations on the effect of light-intensity on the form of plants. The discovery that the process by which the plant assumes its form depends on the influence of rays different from those which take part in photosynthesis, opened an entirely new field of investigation, and rendered the measurement of the highly refractive rays a necessity.

Various methods answering the latter purpose existed, the principal one being that of Bunsen and Roscoe, in which a standard photographic paper is exposed to light; the tone obtained is then compared with a standard black. In the course of the investigations various improvements in the method, such as a substitution of a color-scale for the standard black, suggested themselves. Detailed accounts of method and improvements are scattered through Professor Wiesner's numerous papers, but may be found more especially in his earlier publications.[2]

These measurements of light-intensity are based on the law of Bun-

[1] Wiesner, J. "Untersuchungen über den Lichtgenuss der Pflanzen im Yellowstone Gebiete und in anderen Gegenden Nordamerikas. Photometrische Untersuchungen auf pflanzenphysiologischem Gebiete. (V. Abhandlung.)" *Sitzungsber. d. k. Akad. d. Wiss. in Wien, mathem.-naturw. Klasse*, vol. 114, pt. 1, Feb., 1905.

[2] Wiesner, J. "Photometrische Untersuchungen auf pflanzenphysiologischem Gebiete. (I. Abhandlung.)" *Sitzungsber. d. k. Akad. d. Wiss. in Wien, mathem.-naturw. Klasse*, vol. 102, pt. 1, June, 1893; and "Untersuchungen über den Lichtgenuss der Pflanzen mit Rücksicht auf die Vegetation von Wien, Cairo und Buitenzorg (Java). Photometrische Untersuchungen auf pflanzen-physiologischem Gebiete. (II. Abhandlung.)" *Sitzungsber. d. k. Akad. d. Wiss. in Wien, mathem.-naturw. Klasse*, vol. 104, pt. 1, July, 1895.

sen and Roscoe: "Identical colors of normal papers exposed to light indicate identical products of light-intensity and time." Any tone may therefore be produced by any intensity, but reduced to a definite time, can correspond to one definite (chemical) light-intensity only.

For purposes of measurement of chemical light-intensity, a darkening of the normal paper corresponding to the normal black and brought about in one second, is considered as the unit. If, for instance, the normal black is obtained on the normal paper in 2 seconds, the light-intensity equals $\frac{1}{2}$.

By aid of this method, the light-intensity at any place, on plains, in the vicinity of buildings or groups of trees, inside of the tree-crown, in the shade, in greenhouses, in rooms, etc., can be measured. One can determine the part of the total daylight received by a plant ("relatives Lichtgenuss"), and compare this with the amount of light which, on standard paper, forms the normal tone in one second ("absolutes Lichtgenuss"). In this manner the relation between light-intensity and bud development, form of plant-body, budding and the shedding of leaves was determined. It was found that certain trees use more light than do others, that the portion of total daylight used by trees varies with the time of day, that for some trees this portion is greatest at noon, that for others it is least at the same hour.

Observations were made in Central Europe chiefly, but at times extended to 6° S. lat. and 79° N. lat. This included plains and mountain ranges in temperate climates (Central Europe), arctic regions (Spitzbergen), tropical (Java), and semitropical regions (Egypt). The extension of the experiments to high altitudes remained, more particularly a study of the change in relation between light-intensity and the amount of light used by the plant under the influence of increased altitude.

The mountainous regions of Europe do not offer a desirable field for such investigations, on the one hand because the tree-limit is reached comparatively soon, on the other because extensive plateaus at a considerable elevation above sea-level and easy of access, are lacking. Besides, on account of the numerous cañons and resulting sheltered and exposed places, introducing a vegetation of other altitudes, mixed with regressions, and causing a descent and ascent of species, the continental mountain ranges do not recommend themselves for this purpose.

The extensive American plateaus, however, offer the advantage of a gradual slope from the Atlantic to the Rocky Mountains. This is true in particular of a region beginning with the Missouri valley and

ending at the head-waters of the Yellowstone. One of the chief advantages which this section offers for photometric investigations lies in the very gradual rise of the ground from east to west, beginning with an elevation of but a few hundred meters and finally attaining a height of more than 3000 meters.

Professor Wiesner made use of these natural conditions when, in 1904, he visited the United States. Measurements were made at various points, such as Niagara, St. Paul, Colorado Springs, and Pike's Peak, but the main part of the investigation was carried on in, or in the immediate vicinity of, the Yellowstone Park, during the latter part of August and the early part of September. The medium for study was afforded by 24 herbaceous and 17 woody species.

It was found that an increase in altitude not only means an increase in the intensity of the total daylight, but also an increase in the intensity of the direct (parallel) rays as compared to the intensity of the diffused light. Earlier work[1] had shown that the amount of total daylight used by arctic plants increases as they approach the pole. Measurements in the United States showed that plants ascending to higher altitudes behave in the same manner, but only up to a certain altitude, beyond which a constantly diminishing portion of the total light is used. Evidently the increased intensity of the direct sunlight in high altitudes is not favorable to trees, as shown by the fact that plants, which at lesser elevations do not shed their leaves in summer (Hitzelaubfall), do so at greater altitudes.

A protection against the very intense direct rays is found in the cypress- (pyramid-) shape, adopted by trees in high altitudes (*Pinus murrayana* in the Yellowstone Park). Thus the rays of the midday sun strike the tree at a small angle and hence become much weakened before penetrating the crown. Trees which reach down as far as subtropical regions also have a pyramid-shaped crown, as for instance the cypress, and for the same reason, since this shape protects the trees from the too intense light from the south.

These investigations open a comparatively new field which those who live under favorable conditions will doubtless hasten to enter. The various agricultural experiment stations, for instance, could easily take up such work. In a few years there would be produced

[1]Wiesner, J. "Untersuchungen über den Lichtgenuss der Pflanzen im arktischen Gebiete. Photometrische Untersuchungen auf pflanzenphysiologischem Gebiete. (III. Abhandlung.)" *Sitzungsber. d. k. Akad. d. Wiss. in Wien, mathem.-naturw. Klasse*, vol. 109, pt. 1, 1900.

an accumulation of figures the interpretation of which would be of both scientific and practical value, being applicable to physiological and horticultural problems alike.

H. Hus

Campbell's Mosses and Ferns.[1]—This new edition of a widely used work is so much enlarged and revised as to deserve recognition as such on its title page, rather than to have it announced only in the "Preface to the Second Edition." The extent of the new matter is shown in the increase of the fourteen chapters constituting the body of the former book, by 54 pages, the addition of two entirely new chapters containing about 29 pages, and the increase of the text figures from 266 to 322. The great activity of investigators in this field during the ten years since the first edition was issued, is indicated by the addition of about 180 titles to the bibliography, while some papers referred to in the new text appear to be omitted from the list.

The portion of the text devoted to the Bryophyta is not greatly modified. The changes consist chiefly in the suppression of a few sentences here and there, and the occasional addition of a paragraph or two; *e. g.*, there is a new account of the spermatogenesis of Marchantia based on Ikeno's work. The most striking change is the elevation of the Anthocerotaceæ from the rank of a subordinate "Group" under the Hepaticæ to that of the Class Anthocerotes coördinate with the Hepaticæ and the Musci. This view is not new, for the same disposition of the group was formally made by Howe in 1899, and was followed by Professor Campbell in his *University Text-book* (1902), though neither in the latter work nor here does the author mention the fact. Little new evidence on this question is now brought forward, for the increase in the space devoted to the Anthocerotes is due chiefly to the addition of three new figures. The change has come about through the giving of greater weight to the well known peculiarities of the group, and it is to be welcomed as emphasizing the importance of these plants in phylogeny. It is a pleasure to note that the author has at last begun to adopt a consistent plan of designating orders and families in accordance with the best present usage, though it is unfortunate that he still clings to the clumsy and anomalous terms Jungermanniales Anacrogynæ and J. Acrogynæ. Incidentally

[1] Campbell, D. H. *The Structure and Development of Mosses and Ferns (Archegoniatæ)*. New York, The Macmillan Co., 1905. 8vo, vii + 657 pp., illus.

it might be remarked that the author perpetuates an error of the first edition in stating that Underwood, in substituting for the above terms the names Metzgeriaceæ and Jungermanniaceæ, regarded these families as divisions coördinate with the Marchantiales and Anthocerotes; the latter writer in fact, considered the whole group of the Jungermanniales as of equal rank with the Marchantiales.

In the portion devoted to the Pteridophyta, there is not such a consistent use of the proper ordinal terminations, and the lack of indication as to the rank of the different groups in the main headings will cause much unnecessary trouble for the student who wishes to get a general view of their relative position in classification. The most important change in this section is the removal of the Isoetaceæ from the eusporangiate ferns to a position after Selaginella. There will doubtless be general acceptance of the view that this group is sufficiently distinct to warrant the establishment of a separate order Isoetales; perhaps it might better be regarded as forming a distinct class. It is to be inferred that this may be considered Order II under the Class Lycopodineæ (as in the *University Text-book*), but the author makes no statement on this point, and his rather detailed emphasis on the facts pointing to "a real, but extremely remote relationship between Isoetes and the Eusporangiatæ" may leave the student in doubt as to why this genus is generally connected with the Lycopods. There are many important additions to text and illustrations, particularly in such recently investigated forms as Botrychium, Selaginella, and Isoetes.

One of the new chapters, on "The Nature of the Alternation of Generations," champions the antithetic theory with the same general argument as that advanced by Professor Campbell in the *American Naturalist* in 1902; he considers that the advocates of the homologous theory have not furnished sufficient evidence to substantiate their view. Here as well as elsewhere, the author gives some prominence to Coleochæte as the probable ancestor of the bryophytes. The recent investigations of Allen on chromosome reduction in this genus indicate, to say the least, that it is much further removed from the bryophytes than has been supposed. We should be unwilling to say there is no alternation of generations in Coleochæte; but if the phenomena of reduction are to be made the chief means of interpretation, the sporophyte is undifferentiated, consisting only of the fertilized oöspore, while the first four cells produced in its germination, or possibly the mass of loosely connected cells, may bear a remote comparison to the spores of mosses. Certainly the view held by Campbell and others

that the zoöspores produced by these cells are homologous with the moss spores was not rational; for that zoöspore production is only one method of germination of these cells, depending upon accidental conditions, is proved by the fact that they may grow out directly into filaments, as shown by Chodat and others.

The other new chapter furnishes a convenient but necessarily brief and incomplete *résumé* of the fossil Archegoniates. In the concluding chapter, the author holds mainly the same views as previously: he is inclined to believe that the Spermatophyta are polyphyletic in origin, since the Conifers show the greatest resemblance to the Lycopodineæ, and the Cycads to eusporangiate ferns (through the Cycadofilices); while the Monocotyledons may possibly be derived from aquatic ancestors resembling Isoetes, and the Dicotyledons from the Monocotyledon stock.

There are numerous paragraphs in the first edition where the language is obscure, and we have hoped in vain that these might be made more clear for the benefit of the student who can ill spare time to dig out their meaning. Nevertheless in spite of these and some other defects which might have been remedied without very great labor, it must be said that Professor Campbell has given us a much improved and more usable edition of a valuable book.

T. E. Hazen

Common and Conspicuous Lichens of New England[1] is the title of a series of booklets by R. H. and M. A. Howe. The descriptions are accompanied by some very good photographic reproductions of the lichens in their habitats, as well as by line drawings of the thallus. The work is being issued in parts. Part I contains twenty-two pages; Part II, eighteen pages. The following genera are described in the first two parts — Ramalina, Cetraria, Evernia, Usnea, and Alectoria.

H. S. R.

Czapek's Biochemistry of Plants.[2] — Each year witnesses an increasing interest in the study of biological chemistry. As time goes on the work becomes broader and yields more results. Until recently the subject would have perhaps been more aptly designated as zoö-

[1] Howe, R. H., Jr., and M. A. *Common and Conspicuous Lichens of New England; a Fieldbook for Beginners.* Boston, W. B. Clarke and Co., 1906. 16mo, Parts 1, 2, 40 pp. $1.00

[2] Czapek, F. *Biochemie der Pflanzen.* Jena, Bd. 1, 8vo, pp. xv+584, 1904; Bd. 2, 8vo, pp. 1186, 1905.

chemistry, since most of the investigators busied themselves with the physiological chemistry of animals. Indeed, the term *physiological chemistry* itself is usually understood to deal with the study of animal tissues. Happily, this field which has yielded so richly to the zoölogists, is beginning to be explored more widely by the botanists.

The appearance of Czapek's work marks the beginning of an epoch which should mean much for future work in plant physiology and, indeed, in all other lines which are in any way concerned with the chemistry or physiology of the plant. The author is a well trained botanist, physiologist, and chemist. He gives the reader a truly broad and modern view of the subject in hand, the book being in all senses of the word a *biological* chemistry of plants, not a chemistry of plant organs or plant products. Throughout the entire work, we find the literature on every subject summarized and brought down to date with almost unparalleled accuracy and completeness.

The first volume opens with a brief but comprehensive historical introduction. The General Part treats in a very fundamental manner the physical and chemical processes underlying all vital phenomena. Especial attention is given to the characteristics of colloids, to the general chemistry of enzymes, and to the nature of chemical action in the same.

The Special Part opens with a chapter on the fats and lecithins. Their distribution, metabolism, and storage in plants are made topics of especial interest. In discussing the *rôle* of lecithins, the author shows reluctance in accepting any of the theories which assign to them special *rôles*.

The chemistry and occurrence of the sugars is the subject of a very complete discussion occupying some forty pages. This discussion opens the way for the author's extended treatment of carbohydrate metabolism in the plant. He first treats of the storage of carbohydrates and food value in fungi, bacteria (including alcoholic and other fermentations), seeds, and subterranean storage organs. Then he discusses with great fullness the carbon assimilation of the green organs of plants. Naturally, his treatment is too extensive to be set forth adequately in a review paragraph. Suffice it to say that the author brings together the results of the best work on that subject and discusses it fully from the standpoint of chemistry and biology. The carbohydrates are treated from their origin in the plant to their storage as reserve products in various storage organs.

Following the above subject in quite a logical manner comes the study of the cell wall of the plant. First comes the unmodified cellu-

lose wall of simple plants or plant organs, then the hemicelluloses, pectins, and pentosans, and finally the chemical and physical changes which walls undergo. With these considerations the first volume closes.

The second volume continues the treatment of chemosynthetic activity. More than two hundred pages are devoted to the proteids. Our knowledge of the general chemistry of vegetable proteids and of proteolytic ferments is comprehensively written up and revised to the end of the year 1904. The proteid metabolism of the bacteria, fungi, ripe seeds, seedlings, etc., is given separate treatment. In successive chapters the discussion takes up the proteid bodies, their cleavage by ferments, absorption of the products by the plant, and formation of reserve proteids.

One is gratified to find that the author sets forth at some length the elucidating theory of proteid chemistry based upon the amino-acid constitution. Since this new theory promises to clear up the "mysterious" structure of the "awful proteid," it is proper that it receive a prominent place in any comprehensive work on biochemistry.

The pyridin and chinolin bases are given very full treatment in the discussion of alkaloids.

The phenomena of respiration, fermentation, and oxidizing enzymes are made the principal topics of a long and interesting chapter on the absorption of oxygen by plants. Here, as elsewhere, the author brings out with force and clearness the chemical basis of the activities of living matter. Naturally, the oxidation of carbohydrates and the distribution and constitution of the resulting vegetable acids receive extended treatment at this place. The author is inclined to support the view of Neubauer, that the vegetable acids have the function of neutralizing the inorganic bases which are formed in ripening fruits. The great mass of literature on oxidizing enzymes is carefully brought together and arranged in an orderly manner. The author points out that in many studies of oxidases sufficient care has not been used to exclude other enzymes.

The discussion of "omnicellular cyclic carbon compounds" is largely devoted to quinone, phenols, and tannin. Czapek contends that the concept of "tannin," as used in botany, is altogether too loose, this name being applied to any substance which turns black upon the addition of iron chloride, but many substances like vanillin and morphine react with iron like tannin. He probably sets forth the true estimate of tannin when he shows that it does not perform any one but a variety of functions in the plant.

One hundred and seventy pages are devoted to the *rôle* of the mineral elements in plants. It is probably safe to say that never before has this subject been so scientifically treated, nor has such a wide range of analyses been collected into one work. In no other part of the work does the author show greater breadth of mind and freedom from provincial ideas than in dealing with this oft-debated subject. The discussion treats in separate chapters the *rôle* of the elements in bacteria and fungi, in seeds, in subterranean storage organs, in buds, in the wood of trees, in the bark of trees, in leafy organs (including mosses and ferns), in algæ, in pollen grains, in fruits, and in roots. Not merely are many tables of analyses given, but there is discussion upon the probable value and function of each element to the plant. Much discussion is given to the probable *rôle* of elements like calcium and magnesium, on which much work has been done. In the particular case of these elements, the author brings together the results of a large number of workers with great justice and precision. The work of Loew is naturally given much prominence, yet he thinks that that author has not in all cases taken a sufficiently broad view of the facts, since too great importance is undoubtedly attached to the antagonism of calcium and magnesium.

The last chapter of the book is devoted to a discussion of the responses of plants to chemical stimuli. Under different headings there is brought together the work on the stimulation of protoplasmic streaming; the stimulation of nuclear and cell division; the stimulation of growth by toxic substances; the formative effect of chemical stimuli upon vegetative and reproductive organs.

The book is indispensable to all workers in physiology, whether of plants or animals, as well as in physiological and organic chemistry.

H. S. R.

Lacouture's Liverworts of France.[1] — This elaborate monograph takes the form of a synoptical key which is arranged in three series of tables; the first gives the characters of the tribes, the second of the genera, and the third of the species. Seventy-five genera containing two hundred and twenty-five species are described.

The characters upon which the classification rests are almost entirely those of the vegetative structures, and they are minutely depicted.

[1] Lacouture, Ch. *Hepatiques de la France. Tableaux synoptiques des caractères saillants des tribus, des genres et des espèces.* Paris, P. Klincksieck, 1905. 4 to 77 pp., 200 figures.

The description of each species is accompanied by a distinct figure showing the characteristics of the plant, especially those upon which the classification is based.

Several new genera are created by raising subgenera to the rank of genera. Jungermannia is divided to form the genera Sphenobolus, Lophozia, and Aplozia; likewise, Riccia is divided to form three genera, Ricciocarpus, Ricciella, and Euriccia; Cephalozia, to form Eucephalozia and Cephaloziella.

The work is one which will prove to be very valuable, and it will be particularly useful in classifying material which does not possess the organs of fructification.

H. S. R.

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